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BEAN VARIETAL TESTS FOR DISEASE RESISTANCE[1]

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INTRODUCTION

The discovery or development of disease-resistant varieties of beans (*Phaseolus vulgaris* L.) has been recognized for several years as the most promising line of investigation looking toward the prevention of large annual losses. Several American and European investigators have published valuable evidence on the reaction of the commoner bean varieties to the different diseases. Unfortunately, most of the standard American varieties have proved to be susceptible to one, two, and frequently all the major troubles.

Hybridization has been resorted to, but this is complicated and time-consuming in securing resistance to anthracnose because of the variation in reaction among the varieties to an undetermined number of biologic forms of the causal fungus, *Colletotrichum lindemuthianum* (Sacc. and Magn., B. and C.). No variety resistant to all the known biologic forms has hitherto been reported.

The success of the Cornell workers in combining the specific disease resistance and other desirable characters of two or more varieties of beans into one strain is sufficiently well known to need no review. Considering the many different types of bean varieties, their geographic distribution, climatic adaptation, and market requirements, the necessity for an abundance of resistant types with which to work is realized. The absence of such has been a serious handicap to the plant breeder. This paper presents the results of an extensive search for resistant material.

A large collection of local and foreign varieties and species of beans has been made and tested. Although it was realized that many of the foreign varieties would probably not be adapted to direct commercial utilization in the United States, they might, through possession of unusual resistance to one or more diseases, be valuable for hybridization with susceptible American types. While the information here given is in many respects preliminary in character, in others it seems conclusive enough to warrant bringing it to the attention of other investigators.

NOMENCLATURE AND AUTHENTICITY OF VARIETIES USED

The names adopted by Jarvis (*6*)[3] have been generally used in listing the standard American varieties. Those introduced since the publication of his bulletin in 1908, or of uncertain classification, are

[1] Received for publication June 30, 1924; issued September, 1925.
[2] Resigned April 2, 1925.
[3] Reference is made by number (italic) to "Literature cited," p. 153.

given the names advertised by the seedsmen introducing them. All foreign varieties are listed by the names accompanying the original importation and, excepting the standard European sorts, also the seed and plant introduction number (S. P. I. No.) of the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry through which they were obtained. Information on the European varieties can be readily secured by consulting the accredited seedsmen's catalogues for the years during which the tests were made; or, better, standard horticultural treatises, such as Denaiffe (*4*), and Robinson (*10*), who give also the synonymy. Some of the varieties here included are no longer listed by seedsmen. All lots were carefully examined for trueness to name and very few showed mixtures or sports.

The foreign varieties described by European horticulturists and given English and American names synonymous with standard American varieties are for the most part identical with the American varieties of the same name, as shown by a comparison of the European description with the descriptions of Tracy (*9*), Irish (*5*), and Jarvis (*6*), as well as from the writers' field observations. Occasionally, however, the descriptions do not agree, and the European and American varieties of the same name are obviously different. Even where they are apparently identical in horticultural characteristics, the reaction to disease may be different, and, for the purposes of this study, they are treated separately.

Where no name accompanied the original importation there is given a short description of the seed, based on samples from the original packet. Since many of the non-European foreign varieties were purchased in native markets, varietal mixtures and hybrids were common. Of special interest in this connection is the large assortment of brilliantly colored and variegated types grown by the natives of East Africa, particularly of Urundi Province. Among the beans from this source were many of obviously hybrid origin, as shown by their segregation into various types following the first planting in this country. Except where the amount of crossing was slight, the tests on the samples containing volunteer hybrids have not been published. The mixtures and hybrids were in all cases separated as far as possible from the "type" seed, but in many instances were not tested until 1923, when a larger field plot was available.

Since the original samples in many cases were small, it was necessary to save seed each year from the test rows in order to continue the work. The small percentage of volunteer hybrids resulting from this practice have been largely eliminated by subsequent selection in cases where the variety proved to be of value. Many of the purely tropical varieties failed to mature seed in the latitude of Lansing, Mich., and were later grown for increase purposes in Florida. To what extent the excessive vegetative growth of such types at Lansing may have influenced their natural resistance or susceptibility to the various diseases is not known.

DISEASES INCLUDED IN RESISTANCE STUDIES

Attention has been directed principally toward the discovery of varieties or strains of varieties possessing resistance to bacterial blight (*Bacterium phaseoli* E. F. S.) and to the various biologic forms of the anthracnose fungus (*Colletotrichum lindemuthianum* (Sacc.

and Magn., B. and C.), which are doubtless the two most important diseases of beans in the eastern United States. Incidental to tests with these diseases, notes were made on the natural occurrence and severity of mosaic. The work in 1923 also included greenhouse and field inoculations with bacterial wilt (*Bacterium flaccumfaciens* Hedges), a disease until recently confused with bacterial blight, and of increasing economic importance in the northern bean sections.

Authentic virile cultures of the bacterial blight and wilt organisms were obtained from Florence Hedges, of the Laboratory of Plant Pathology of the Bureau of Plant Industry, United States Department of Agriculture, and by isolations from typically diseased plants from Michigan and New York. Tested cultures of the *alpha*, *beta*, and *gamma* biologic forms of the anthracnose fungus were obtained from W. H. Burkholder, of Cornell University; and the eight biologic forms (Nos. I to VIII, inclusive), as well as samples of the bean varieties and strains used to differentiate them, were kindly furnished by J. G. Leach, of the University of Minnesota. The *alpha* and *beta* forms only were used in the inoculations of 1920 to 1922, inclusive, while in 1923 there were added the *gamma* form described by Burkholder (*2*) and also the above-mentioned eight biologic forms recently described by Leach (*8*). Since some of the varieties listed in Table II were not tested in 1923, they were presumably exposed only to the first two forms, a possibility which should be remembered in judging their behavior. Although some separate greenhouse inoculations are recorded in this paper for certain of the forms, no detailed study to determine resistance or susceptibility to individual biologic forms has been made. The object has been to find, if possible, suitable types immediately available for the plant breeder, which combine resistance or immunity to all the forms. The whole subject of biologic forms in the bean Colletotrichum requires further investigation and, at least until the relationships between the 11 forms thus far reported are established, extensive variety testing with individual forms is scarcely advisable.

LOCATION, DURATION OF TESTS, AND METHODS EMPLOYED

FIELD STUDIES

The field investigations here reported extend over the period 1920 to 1923, inclusive. In 1920 a single test plot was located near Saginaw, Mich., in cooperation with the local farm bureau. During the succeeding years the work was centered at East Lansing, Mich., where land, laboratory facilities, and much assistance were furnished by the departments of botany and farm crops of the Michigan Agricultural College.[4] Since weather conditions frequently prohibit the best development of anthracnose at Lansing, it was necessary, in order to obtain a severe test of the varieties every season, to establish additional plots containing partial replications of the Lansing test in more favorable places. Accordingly in 1921 and 1923 a plot was maintained in the northern peninsula of Michigan near McMillan in cooperation with the Jerome B. Rice Seed Co. In 1923, one was placed in the northern "Thumb" section of Michigan near Bad Axe, in cooperation with the local farm bureau, and another at St. Paul,

[4] Credit is due G. A. Meckstroth for assistance at Saginaw during 1920, and to E. F. Hopkins, E. V. McKenna, and Zadik Voscan for handling the details of the work at East Lansing in 1923.

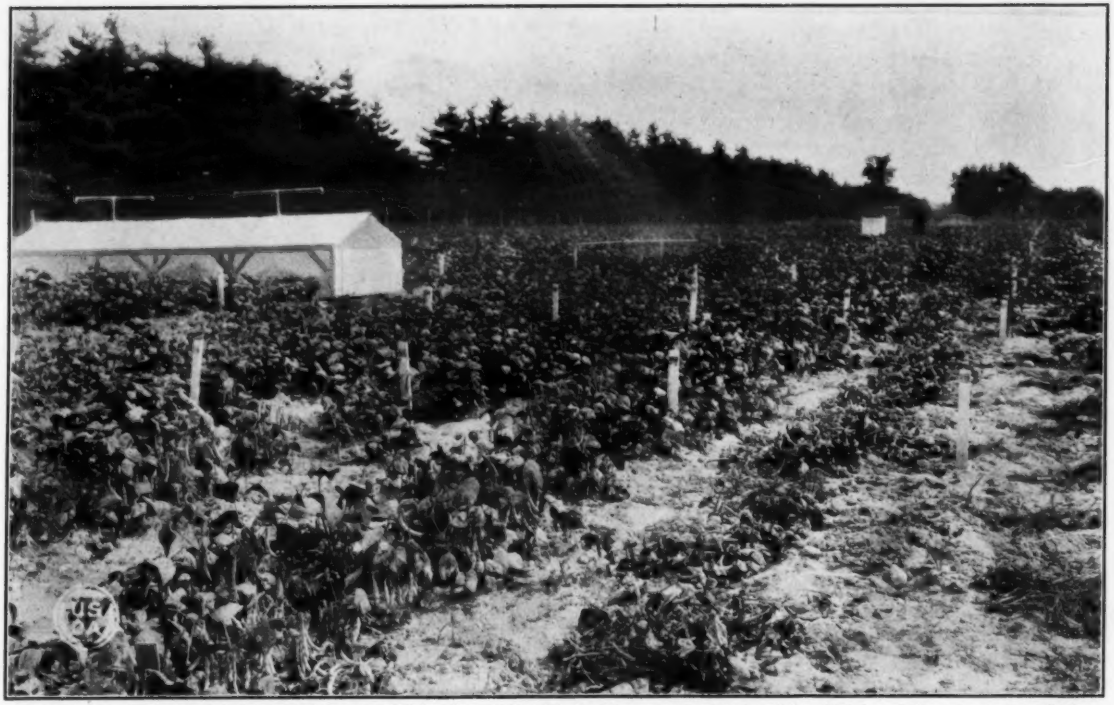
Minn. The Minnesota test was conducted by J. G. Leach, who planted the seed, made the inoculations, and kindly furnished the authors with a copy of his notes on disease prevalence.

The field plots were generally laid off in rows, 3 to 4 feet apart and from 100 to 200 feet long, divided into rod units, each unit being planted to a single variety which was sometimes replicated in other parts of the same plot. As a rule every tenth row was planted with infected seed of a very susceptible type, to serve as a control and to supply inoculum to the adjacent lots.

In addition to frequent artificial inoculations, natural infection and spread of the diseases were facilitated by scattering between the rows severely diseased vines collected and preserved from the previous year. The artificial inoculations were made by atomizing the plants from three to five times during the season under moist weather conditions, with combined spore suspensions from pure cultures of the different biologic forms of *Colletotrichum lindemuthianum* and with bacterial suspensions of the blight organism. No separate inoculations with the biologic forms of anthracnose were undertaken in the field.

In an acre portion of the 1923 East Lansing plot the most resistant varieties and selections discovered during the preceding years were segregated and given an unusually severe test. Following the method employed by Burkholder and Emerson of Cornell infected seed of very susceptible varieties were planted in "buffer" rows spaced about 12 inches from the supposedly resistant type to be tested. Abundant infection was further secured in this plot by the aid of oscillating sprinklers and by cheesecloth inoculation cages kept continuously moist by properly directed spray nozzles (pl. 1).

The bacterial-wilt inoculations, limited to preliminary tests in the summer of 1923, were made both on young seedlings and on tender growing parts of older plants. Ten plants of each variety were inoculated when 8 to 12 days old by simply jerking off one or both of the shrunken cotyledons prior to formation of the abscission layer and applying a drop of bacterial suspension from a 3 to 4 day old potato cylinder culture. The figures in the eleventh column of Table II give the results of these tests. The first series of inoculations on older plants was made when the plants were approximately 3 weeks old. The bacteria were pricked into the young growth, stems, petioles, and runners, at 2 or 3 different parts of the plant, with a flamed needle. Since after 10 days but few of the varieties showed evidence of infection, a second attempt was made, in which not only the young growing parts but also the main stems were inoculated. A large number of the varieties still remaining uninfected up to the flowering and podding stage were inoculated a third time in the same way, but again without much success. As shown later the "cotyledon method" was found much more certain of securing constant and uniform infection and was much quicker, but the period in the growth of the plant during which it can be carried out is too short to permit inoculation of a large number of varieties. It should be done only during the stage of growth indicated, since removal of the cotyledons too early is obviously injurious to the plant, and after the abscission layer is formed the vessels in which the bacteria enter are of course closed.



General view of experimental plot at East Lansing, Mich., August 10, 1923, showing arrangement of varieties, cloth inoculation cage, and oscillating sprinklers for producing artificial epidemics of anthracnose and bacterial blight

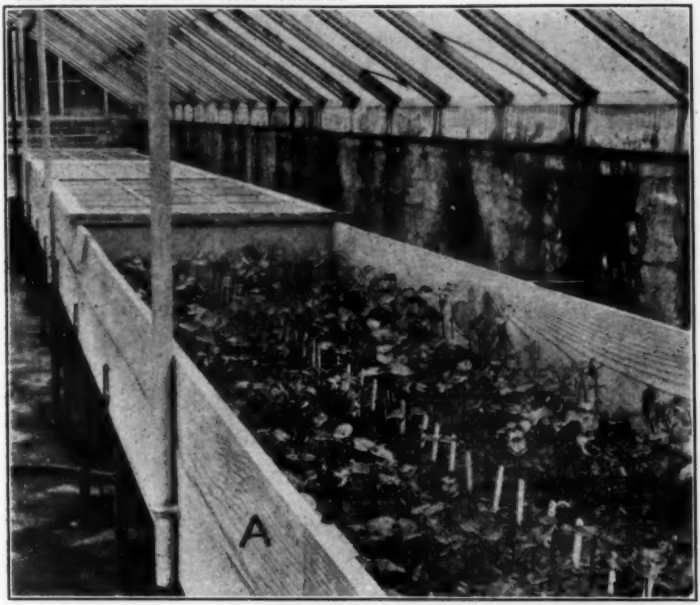
GREENHOUSE STUDIES

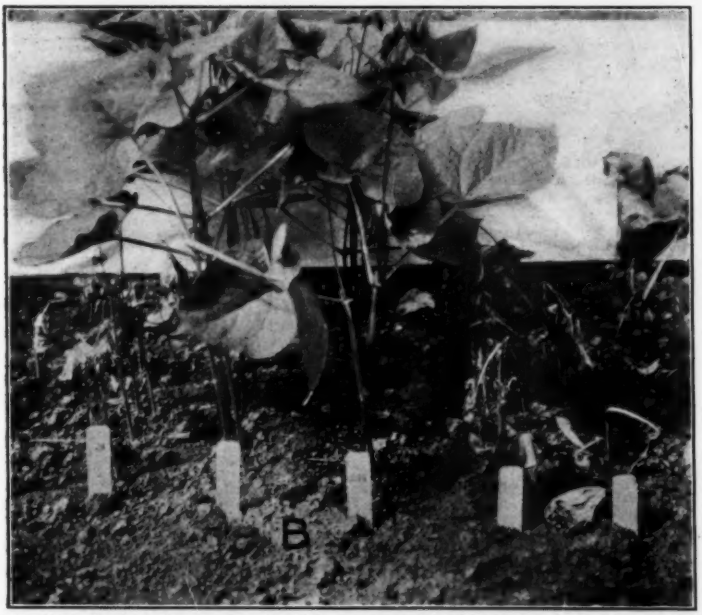
The greenhouse inoculation tests were conducted during the winters of 1922–23 and 1923–24 at Arlington Experiment Farm, near Rosslyn, Va., and were limited to anthracnose and bacterial wilt. Although considerable time has been given the problem, the writers have thus far failed to develop a satisfactory greenhouse method for obtaining quick and conclusive evidence on the relative susceptibility of varieties in the seedling stage to bacterial blight.

Since most of the American varieties have been tested by Barrus (*1*) for their separate reaction to the *alpha* and *beta* biologic forms of the anthracnose organism, principally foreign varieties were included in the authors' greenhouse studies. These were inoculated separately with the *alpha* form, and on account of the great similarity of the *beta* and *gamma* forms, as shown by the work of Burkholder (*2*), the comparative unimportance of the *gamma* form and limitations in greenhouse space these two forms were usually combined. All of the eight Minnesota forms were likewise combined, and to these were added in one inoculation (reported in Table III) the above-mentioned three forms from Cornell, the object being to obtain a control on the field results and, as already mentioned, to find varieties resistant to all known forms.

The different lots were planted in fresh loam soil in regular greenhouse benches with the sides raised 6 inches above the soil in order to turn them into moist chambers after inoculation by covering with wet burlap-lined coldframe sashes (pl. 2, A). Ten seeds of each variety were spaced 2 inches apart in short rows extending crosswise in the bench, and in every tenth row controls known to be susceptible to the biologic form being tested were planted. White Navy and Boston Pea were used most frequently for controls on *alpha*, Improved Golden Wax and ordinary Red Kidney for *beta*, and Well's Red Kidney, White Imperial, and Nova Scotia Marrow for *gamma*. The differential varieties and strains used as controls on the Minnesota biologic forms were planted in small pots and inoculated separately with each form in another greenhouse and then returned to spaces left vacant in the bench among the varieties to be tested, which in the meantime had been sprayed with a combined spore suspension of all the forms. In this way one could make sure that all cultures were virile and acting upon the varieties under the conditions of the test. The plants were inoculated as soon as possible after germination and kept moist by aid of the wet covering for 48 hours. The temperature ranged from 18 to 20° C. for the first few days, but later often went much higher. The results were recorded in all cases 10 days after inoculation. Plate 2, B is a typical illustration of the decisive outcome of experiments of this sort. From the above description it is seen that the temperature, time, and other conditions followed closely the standardized and very satisfactory procedure originally used by Barrus (*1*) and subsequently confirmed by the infection studies of Lauritzen (*7*).

The greenhouse wilt inoculations were made on plants grown in benches as above described and generally by the "cotyledon method." The temperature was held at about 25° C., and notes on permanent wilting of one or more of the first trifoliate leaves, as illustrated in Plate 3, B, were made one, two, and three weeks after





A.—View of a typical anthracnose inoculation experiment in the greenhouse, showing arrangement and size of plants at the time of inoculation. The farther end of the bench has already been sprayed with the inoculum and covered with wet burlap-lined sashes

B.—Results of an anthracnose inoculation experiment on seedlings in the greenhouse, illustrating immunity and extreme susceptibility among five varieties of African beans. The varieties used in this test were planted Feb. 13, inoculated with a heavy spore suspension of the *alpha* biologic form of *Colletotrichum lindemuthianum* Feb. 26, and photographed 10 days later, Mar. 8, 1923.

A.—A severe case of bacterial wilt developing on a nearly full grown plant in the field; most of the leaves are wilted or dead and the few pods are poorly filled, a condition illustrating the extent of infection defined as "severe" for this disease in Table I

B.—Results, 20 days after inoculation with the bacterial wilt organism in young epicotyls, at the second-leaf stage, of the Black Valentine variety. The general retardation of growth of two inoculated plants and permanent wilting of leaves are typical of the greenhouse infections reported in this paper

inoculation. It soon became evident, however, that wilting alone was a poor index for comparison, since practically all plants inoculated showed this symptom. On account of more or less abnormal growth of both inoculated and control plants under ordinary greenhouse illumination in the winter, it was unfortunately not practicable to conduct the experiments for a longer period. A number of tests on potted plants carried for two months brought out much greater differences and showed that a longer experimental period is essential. The field seedling inoculations, therefore, gave a much better test of the ultimate effect of this disease on the plant than either the greenhouse seedling tests or the field inoculations on older plants.

WEATHER CONDITIONS AND PREVALENCE OF ANTHRACNOSE AND BLIGHT DURING THE PERIOD OF TEST

ANTHRACNOSE

During the entire period 1920 to 1923, inclusive, weather conditions were in general unfavorable for natural spread of anthracnose at both the Saginaw and East Lansing plots. At McMillan, Mich., on the other hand, epidemics developed during both years (1921 and 1922) that plots of American varieties of beans were maintained there. The usual midseason hot, dry spell at Lansing effectively checked the spread of the disease until the cool, moist weather of late summer. Conditions in 1920 and 1923 were not so unfavorable as to prevent the obtaining of abundant infection by repeated artificial inoculations, so that not only were epidemics produced in the two 1923 Michigan plots, but Doctor Leach reported satisfactory results in the duplicate established at St. Paul, Minn. A fairly decisive test was, therefore, obtained on all varieties planted in 1923.

BACTERIAL BLIGHT

Bacterial blight was generally prevalent and severe in all test plots during 1920, 1921, and 1923, and also on the late varieties following the extreme dry period of 1922. The disease was so destructive in parts of the Michigan bean section in 1921 that a number of fields of Red Kidneys were not harvested.

RECORDS OF DISEASE PREVALENCE

The data on the reaction of each variety to the various diseases, obtained from the different field plots during the entire period of test and from the greenhouse inoculations, have been critically reviewed and classified according to six standard grades of infection extending from very severe at the one extreme to none at the other. Brief definitions of these classes, which necessarily depend upon a different set of symptoms for each disease, are given in Table I.

Unfortunately sufficient knowledge of the diseases and refinement of techinque are lacking to enable one to give a more definite expression of resistance or susceptibility than is shown by the headings of Table I. This is especially true in the case of bacterial wilt, where the progress of the disease under varying field conditions is poorly understood. Likewise difficulties are encountered in attempting to define clearly what appear to be intermediate degrees of susceptibility to bacterial blight. For mosaic, prevalence has been largely relied upon, although, as mentioned earlier, the data on this disease were obtained incidentally as they were available in the course of the other studies.

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TABLE I.—*Definitions of terms used to express the extent or degree of infection obtained from artificial inoculation and from natural spread of the different diseases*

Disease	Extent of infection					
	Very severe	Severe	Moderate	Slight	Very slight	None
Anthracnose	Seedling usually dies. Lesions are deep and usually numerous on epicotyl and parts above. Pods become much spotted with deep lesions and rarely mature many seeds.	Seedling usually survives. Lesions are numerous on epicotyl, petioles, veins and pods and may be large and deep but usually do not seriously hinder development of most of the pods formed.	Seedling recovers from the infection. Lesions, although numerous on stems, leaves, and pods, not usually deep or extensive, and seed infection is rare.	Development of seedling apparently unaffected by the disease. Plant may show numerous lesions, but they are small in extent and mostly confined to ridges on stem, petiole, and to leaf veins.	Infection varies from small, black, definite lesions without spores to pale or brownish flecks.	Light flecking to cases where no evidence of infection whatever.
Bacterial blight	The plants appear yellow and burned and are largely defoliated with extensive lesions also on stems and pods which dry up with but few normally developed seeds. Seed infection may occur.	Leaves show many large spots, some yellowing and burning, but remain largely on the plant until maturity. Pods have numerous spots, are often poorly filled, but succeed in maturing a fair proportion of the seeds. Seed infection may occur.	Leaf lesions generally small, quickly limited by the larger veinlets and, although causing pronounced yellowing in some cases, rarely result in extensive defoliation. Pod lesions are few, small and shallow.	Numerous small lesions are tardily formed, but apparently have no effect on development of plant nor on normal ripening of the pods.	Occasional very small brown spots or flecks appear on both leaves and pods, but almost entirely disappear with further growth of the plant.	Faint translucent flecks may appear following inoculation, but quickly disappear with further growth.
Bacterial wilt	Plant is either killed outright in the seedling stage or lingers from a few weeks to a month and a half, in a much dwarfed condition with most of the older leaves flaccid or dead and the younger leaves gradually becoming affected until finally the entire plant succumbs.	Entire plant is dwarfed with numerous partially wilted or dead branches or leaves. Pods are few and poorly filled and a portion of the seeds show a yellow bacterial layer beneath the seed coat.	Plant is noticeably dwarfed or, in case of pole varieties, has a distinct spindling and unhealthy appearance with shrivelling and shedding of the older foliage. Many pods are normally developed and ripened, but may bear infected seed.	Plant as a whole apparently recovers, although occasional branches and leaves are wilted or dying, and a small proportion of the pods fail to fill out. Seed infection may occur even on apparently healthy parts.	Development of plant is apparently unaffected by the disease, although in the early stages of growth incipient or permanent wilting of one or more of the first leaves and occasional defoliation may occur. Seed infection infrequent.	No evidence of infection whatever.
Mosaic	75 to 100 per cent of the plants show severe dwarfing and failure to set many pods.	50 to 75 per cent of the plants show pronounced symptoms, as dwarfing and distortion of leaves.	25 to 50 per cent of the plants are noticeably affected.	10 to 25 per cent of the plants are noticeably affected.	1 to 10 per cent of the plants are noticeably affected.	No evidence of the disease.

In case of anthracnose it will be noted that the writers have followed very closely the definitions adopted by Barrus (*1, p. 593*) as a result of his extensive studies of this disease. The terms express the general effect of the disease on the plant, which takes into consideration both the number and size of the lesions, although, as Leach (*8*) has recently pointed out, size of lesion is doubtless the more important index of resistance.

In Table II there are listed all the varieties and selections of *Phaseolus vulgaris* which have been tested and, in successive columns, their reaction to the different diseases as expressed by the summary terms defined in Table I.

In examining the detailed records positive evidence was necessarily given most weight. Negative evidence, or signs of resistance, was considered significant only after comparison with controls and the behavior of the variety in the greenhouse and in other plots in different years. Unfortunately many of the varieties have not been tested long enough or under the necessary conditions to make such comparisons possible, and final judgment must await additional information.

The experimental results for bacterial blight on many of the American varieties, as shown in the ninth column, are supported by extensive observations in seedsmen's trial grounds and in large field areas growing in Michigan, New York, and Vermont.

The first column devoted to bacterial wilt gives the results of seedling inoculations in the greenhouse, the figures expressing the percentage of the total number of plants which showed permanent wilting of one or more of the first trifoliate or true leaves. The second column gives the field record. Here the occasional figures represent those varieties which were inoculated by the "cotyledon method" and show the percentage of plants, based on a unit of 10, which either died from the effects of the disease or were so stunted as not to mature pods. The surviving plants generally also displayed varying degrees of dwarfing, but usually succeeded in ripening many of their pods. The words in this column expressing different degrees of infection refer to the inoculations on older plants by the needle-prick method, described in the preceding section.

EVIDENCE OF RESISTANCE

A review of Table II shows the comparatively small number of varieties which were not moderately or severely infected with both anthracnose and bacterial blight, the diseases given special attention in this study. A large proportion of those tested but one season and showing the extent of infection indicated by "slight" or "none" would doubtless also have proved more or less susceptible had they been tested under more favorable conditions for the development of disease.

Since the evidence on resistance to anthracnose in the case of a number of the varieties was based largely on their behavior in the field, these and a number of others concerning which the information in Table II is uncertain or lacking were subjected to a final greenhouse test with all the known biologic forms of the fungus. The detailed results of this experiment, which was carried out in triplicate, are presented in Table III.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans (Phaseolus vulgaris L.) to greenhouse and field inoculations with anthracnose (Colletotrichum lindemuthianum), bacterial blight (Bacterium phaseoli), and bacterial wilt (Bacterium flaccumfaciens), and records on the natural occurrence of mosaic*

(Varieties found most resistant to anthracnose blight or wilt are shown in italics. See reference letters *a*, *b*, and *c* and footnotes)

AMERICAN VARIETIES

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms						
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection	Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
		Dwarf varieties with wax pods									
1		Best Yet	Bolgiano	1920, 1921, 1923	No data	No data	Severe	Moderate	43	41	Slight.
2		Black Wax	Rice	1921, 1923	do	do	Moderate	do	100	None	Do.
3		Brittle Wax	Burpee	1920–1923	do	do	Very severe	Very severe	100	Severe	Do.
4		Burpee Kidney Wax	do	1920–1923	do	do	Moderate	Slight to moderate.	67	do	Severe.
5		California Rust-proof	Bolgiano	1920, 1921, 1923	do	do	Severe	Moderate	100	do	Slight.
6		*Challenge Black Wax*	Ferry	1920–1923	do	do	do	Severe	80	20 [c]	Moderate.
7		Crystal Wax	Rice	1920, 1923	do	do	do	do	57	None	Do.
8		*Currie Black Wax*	do	1920–1923	do	do	do	do	88	20 [c]	Slight
9		Davis White Wax	do	1920, 1921, 1923	do	do	Very severe	do	100	90	Moderate.
10		Detroit Wax	Ferry	1920, 1923	do	do	Severe	do	100	No data	Severe.
11		Dwarf Golden Carmen	Roger Bros	1923	do	do	None	Moderate	No data	None	None.
12		Flageolet Wax, green	Unknown	1922	do	do	No data	Slight	do	No data	No data.
13		Flageolet Wax, scarlet	Ferry	1920, 1921, 1923	do	do	Severe	Severe	100	None	Moderate.
14		Flageolet Wax, violet	Rice	1920–1923	do	do	Very severe	do	100	Slight	Severe.
15		German or Saddleback	Burpee	1922–1923	do	do	do	do	100	Moderate	Do.
16		Golden Eye Wax	Rice	1920, 1921, 1923	do	do	Slight	do	50	None	Moderate.
17		Golden Wax, old style	Ferry	1920–1923	do	do	Very severe	Very severe	100	do	Slight.
18		Golden Wax, improved	Rice	1920–1923	do	do	do	do	86	do	Do.
19		*Hodson Wax*	do	1920–1923	do	do	Slight	Slight [b]	100	do	Severe.
20		*Keeney Rustless*	Ferry	1920–1923	do	do	do	do [b]	100	Moderate	Do.
21		Lima Wax	Roger Bros	1920	do	do	None	Severe	No data	No data	Slight.

22	Michigan White Wax	Ferry	1920–1923	do	do	Very severe	do	100	None	Do.
23	New Hardy Wax	Stump & Walter.	1923	do	do	do	do	No data.	Severe	Moderate.
24	Pencil Pod Black Wax	Rice	1920–1923	do	do	do	Very severe	do	Slight	Do.
25	Prolific Black Wax	Dreer	1920–1923	do	do	do	Moderate	100	Severe	Severe.
26	Refugee Wax	Ferry	1920–1923	do	do	Moderate	do	70	None	Very Severe.
27	Roger Improved Kidney Wax.	Roger Bros	1923	do	do	do	Severe	No data.	Severe	Slight.
28	Round Pod Kidney Wax	Rice	1920–1923	do	do	Severe	do	89	do	Severe.
29	Rust-proof Wax	Ferry	1921	do	do	do	do	No data.	No data	Slight.
30	Sure Crop Wax	Rice	1920–1923	do	do	Very severe	do	90	None	Do.
31	Trucker's Reward	Bolgiano	1923	do	do	Severe	Moderate	No data.	Severe	None.
32	Unrivalled Wax	Ferry	1920–1923	do	do	Moderate	do	100	Moderate	Slight.
33	Vaughn's Monster Wax	Vaughn	1923	do	do	Very severe	Severe	No data.	Severe	Moderate.
34	Wardwell	Rice	1920–1923	do	do	Severe	do	do	do	Severe.
35	Webber Wax	do	1920–1923	do	do	do	do	do	None	Do.
36	Yosemite	Henderson	1922–1923	do	do	do	do	100	Severe	Do.
	Dwarf varieties with green pods									
37	Bayo	Morse	1920, 1922, 1923	No data	No data	Very severe	Severe	No data.	Moderate	Slight.
38	Black Valentine	Rice	1920–1923	do	do	Severe	Very severe	do	None	Do.
39	Bountiful	do	1920–1923	do	do	Very severe	Severe	100	Slight	Do.
40	Burpee Stringless	do	1920–1923	do	do	do	do	100	Severe	Do.
41	Canadian Wonder	Fish	1920–1923	do	do	Severe	Very severe	90	Moderate	Moderate.
42	China Red Eye	Rice	1920, 1921, 1923	do	do	Very severe	Moderate	80	None	Do.
43	Dwarf Horticultural	do	1920–1923	do	do	do	Severe	100	do	Severe.
44	Fordhook Favorite	Burpee	1920, 1921, 1923	do	do	Severe	Moderate	63	Moderate	Do.
45	*French's Horticultural*	Rice	1922, 1923	do	do	Slight	Slight [b]	78	Slight	Do.
46	Full Measure	do	1920, 1921, 1923	do	do	Very severe	Severe	100	do	Moderate.
47	Giant Stringless	do	1920–1923	do	do	Severe	Moderate	100	None	Severe.
48	Goddard, Improved	do	1920, 1921, 1923	do	do	Moderate	Severe	100	do	Slight.
49	Hodson Greenpod	Ferry	1920, 1921, 1923	do	do	Severe	do	No data.	do	Do.
50	Lady Washington	Morse	1920, 1922, 1923	do	do	do	do	100	do	Very severe.
51	Longfellow	Rice	1920, 1923	do	do	do	Very severe	60	do	Slight.
52	Low Champion	do	1920, 1921, 1923	do	do	Very severe	do	50	Slight	Severe.
53	Marrow, Nova Scotia	Cornell University.	1920–1923	do	do	Severe	Moderate	No data.	None	Do.
54	Marrow, White	Rice	1920–1923	do	do	do	Severe	75	do	Do.
55	Masterpiece	do	1920–1923	do	do	Very severe	Very severe	88	do	Slight.
56	Mohawk	do	1920, 1921, 1923	do	do	Severe	Severe	100	do	Moderate.
	Navy Pea types:									
57	Blue-pod Navy	Saginaw, Mich.	1920	do	do	do	do	No data.	No data	Severe.
58	Blue Pod, small white	California	1920	do	do	No data	Moderate	do	do	Do.
59	Boston Pea	Rice	1920, 1921, 1923	do	do	Very severe	Severe	do	None	Do.
60	Dwarf White Navy	Ferry	1920, 1921	do	do	Severe	do	do	No data	Slight.
61	Early Navy	Will	1920, 1921	do	do	do	do	do	do	Severe.

[b] Resistant to bacterial blight.

[c] Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

AMERICAN VARIETIES—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms						
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection	Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
		Dwarf varieties with green pods—Continued									
		Navy Pea types—Contd.									
62		Early Wonder	Michigan station.	1923	No data	No data	Very severe	Moderate	88	None	Severe.
63		Improved Navy	Vaughn	1920, 1922, 1923	do	do	Moderate	Severe	100	do	Do.
64		Navy Pea	Michigan	1920	do	do	do	do	No data.	No data.	Do.
65		Pea Bean or Tree	Burbank	1920	do	do	No data	do	do	do	Do.
66		Pea Bean	Michigan	1920	do	do	do	do	do	do	Do.
67		Pilot Navy	Will	1920, 1921	do	do	Very severe	Very severe	do	do	Do.
68		Prolific Tree	Farquhar	1920, 1921	do	do	Severe	Severe	do	do	Slight.
69		Small White Navy	Michigan station.	1923	do	do	Very severe	do	do	None	Severe.
70		do	Saginaw, Mich.	1920	do	do	do	do	do	No data	Do.
71		White Navy	Bolgiano	1920, 1921	do	do	Severe	Very severe	100	do	Do.
72		*Robust (Olaf Nelson selection).*	Michigan station.	1922, 1923	do	do	do	Slight [b]	No data.	None	None.
73		Robust No. 40520	do	1923	do	do	Slight	Moderate	do	do	Do.
74		"Robust Pea"	Burpee	1923	do	do	Very severe	Severe	do	do	Severe.
75		Red Kidney	Rice	1920–1923	do	do	do	Very severe	61	do	Slight.
76		Red Kidney, Wells'	Cornell station.	1920–1923	do	do	Slight	Severe	No data.	Severe	Do.
77		Red Valentine	Rice	1920–1923	do	do	Severe	do	do	None	Moderate.
78		Refugee, Extra Early	do	1920–1923	do	do	do	do	100	do	Slight.
79		*Refugee 1000–1*	do	1920–1923	do	do	Slight	Slight [b]	83	do	Very severe.
80		*Refugee, Roger selection*	Roger Bros.	1921, 1922, 1923	do	do	Moderate	Slight to moderate. [b]	60	do	Severe.

81	----------	Round Six Weeks	Ferry	1920-1923	----do----	----do----	Very severe	Severe	95	Slight	Slight.
82	----------	Tennessee Green Pod	----do----	1920-1923	----do----	----do----	Moderate	----do----	95	None	Do.
83	----------	Turtle Soup	Henderson	1920, 1922, 1923	----do----	----do----	Very severe	Very severe	100	----do----	Severe.
84	----------	Warwick	Clark	1922, 1923	----do----	----do----	Moderate	Severe	No data	----do----	Slight.
85	----------	*White Imperial*	Lyons, N. Y.	1920, 1921, 1923	----do----	----do----	Very slight	Slight [1]	100	----do----	Severe.
86	----------	White Kidney	Rice	1920-1923	----do----	----do----	Severe	Very severe	100	Slight	Moderate.
87	----------	Wonder Forcing	Stump & Walter.	1923	----do----	----do----	Moderate	Severe	No data	None	Slight.
88	----------	Yellow Six Weeks	Ferry	1920-1923	----do----	----do----	Very severe	----do----	78	----do----	Do.
		Pole varieties with wax pods									
89	----------	*Baldwin Wonder*	Ferry	1920, 1921, 1923	No data	No data	Moderate	Slight [1]	60	None	Slight.
90	----------	Golden Cluster	Rice	1920-1923	----do----	----do----	Severe	Moderate	88	----do----	Severe.
91	----------	Indian Chief	Ferry	1920, 1921	----do----	----do----	----do----	Severe	No data	No data	Do.
92	----------	Kentucky Wonder Wax	Rice	1922, 1923	----do----	----do----	----do----	Moderate	44	None	Slight.
93	----------	Mont d'Or	Farquhar	1920, 1921	----do----	----do----	Very severe	Very severe	No data	No data	Do.
		Pole varieties with green pods									
94	----------	Burger Stringless	Rice	1923	No data	No data	Severe	Severe	No data	Slight	Severe.
95	----------	Case Knife	----do----	1920-1923	----do----	----do----	----do----	----do----	100	None	Do.
96	----------	Creaseback	----do----	1920-1923	----do----	----do----	----do----	Moderate	100	----do----	Slight.
97	----------	Cut Short	----do----	1920, 1921, 1923	----do----	----do----	----do----	----do----	88	----do----	Severe.
98	----------	Harlequin	----do----	1920, 1921, 1923	----do----	----do----	Moderate	----do----	100	----do----	Do.
99	----------	Kentucky Wonder	Fish	1920-1923	----do----	----do----	Severe	Severe	66	----do----	Slight.
100	----------	Lazy Wife	Rice	1920, 1921, 1923	----do----	----do----	Very severe	Moderate	60	----do----	Severe.
101	----------	*London Horticultural*	----do----	1920, 1921, 1923	----do----	----do----	Severe	Slight [1]	No data	----do----	Do.
102	----------	McCaslan	----do----	1923	----do----	----do----	Moderate	Moderate	70	----do----	None.
103	----------	St. Louis Perfection White	Ferry	1920, 1921, 1923	----do----	----do----	----do----	----do----	No data	----do----	Slight.
104	----------	St. Fiacre	Farquhar	1920, 1921	----do----	----do----	Severe	Severe	83	No data	Do.
105	----------	*Scotia (Striped Creaseback)*	Rice	1920, 1921, 1923	----do----	----do----	Moderate	Moderate	33	None	Do.
106	----------	Tennessee Wonder	----do----	1923	----do----	----do----	Slight	----do----	No data	----do----	Severe.
107	----------	*Worcester Mammoth*	----do----	1920-1923	----do----	----do----	Severe	Slight [1]	70	Slight	Do.

ARGENTINE VARIETIES

(Seed obtained through American Consular Service)

108	46491	Colorados (Arroyo Seco)	Santa Fe Province.	1920	No data	No data	None	Very severe	No data	No data	Slight.
109	46494	Mendocinos	Mendoza Province.	1920	----do----	----do----	----do----	Slight	----do----	----do----	None.
110	46495	Salteño	Salta Province	1920	----do----	----do----	----do----	Very severe	----do----	----do----	Slight.
111	46162	Salteños	Buenos Aires	1920	----do----	----do----	----do----	----do----	----do----	----do----	Do.
112	46493	Sanjuanino	San Juan Province.	1920	----do----	----do----	----do----	Moderate	----do----	----do----	Do.

[1] Resistant to bacterial blight.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

BELGIAN CONGO VARIETIES

(Seed presented by J. Burtt-Davy, Johannesburg, Transvaal)

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties									
113	48472–A	Long, slender tan beans	Elizabethville	1922	No data	No data	None	Slight	No data	No data	Slight.
114	48472–B	Long, flat light red beans with dark red stripes and markings (similar to No. 612 from Urundi).	do	1922, 1923	None	Severe	Moderate	Moderate	79	do	Do.
115	48472–C	*Large, light brown beans with greenish brown stripes (some sporting).*	do	1922, 1923	do	None	Very slight [a]	Slight [b]	90	80	Do.
116	48472–D	Long, plump, purple mottled beans with dark ring.	do	1922, 1923	Very severe	Severe	Moderate	Moderate	90	No data	Severe.
117	48472–E	*Small, wine-red kidney beans with dark stripes (similar to 599 from Urundi).*	do	1922, 1923	None	Very slight	Very slight [a]	Severe	89	100	Slight.
118	48472–F	*Light, kidney-shaped beans with violet to blue stripes (similar to 608 from Urundi).*	do	1922, 1923	do	Slight	Slight [a]	Slight [b]	100	100	None.

BRAZIL

(Seed obtained through American Consular Service)

119	46067	Amarello	Santos	1920	No data	No data	None	Slight	No data	No data	Slight.
120	46263	Anão amarello	Rio de Janeiro	1920	do	do	do	Severe	do	do	Severe.
121	46270	Anão cavallos	do	1920	do	do	do	do	do	do	Do.
122	46266	Anão flageolet	do	1920	do	do	do	Moderate	do	do	Moderate.
123	46277	Branco	do	1920	do	do	do	Severe	do	do	Very severe.
124	46324	do	Rio Grande	1920	do	do	do	do	do	do	None
125	46207	do	Sao Paulo	1920	do	do	do	do	do	do	Very severe.
126	46069	Branco grande	Santos	1920	do	do	do	Moderate	do	do	Slight.
127	46070	Branco mindo	do	1920	do	do	do	Severe	do	do	Severe.
128	46208	Canario	Sao Paulo	1920	do	do	do	Very slight	do	do	Slight.
129	46322	Carico	Rio Grande	1920	do	do	do	Moderate	do	do	Moderate.
130	46515	Carrapato	Para	1920	do	do	do	Severe	do	do	None.
131	46209	Cavallo brancos	Sao Paulo	1920	do	do	do	Very slight	do	do	Slight.
132	46210	Cavallo marrão	do	1920	do	do	do	Slight	do	do	Very slight.
133	46211	Cavallo mulatinho	do	1920	do	do	do	Severe	do	do	Moderate.
134	46325	Da praia	Rio Grande	1920	do	do	do	do	do	do	Severe.
135	46264	De seger preto	Rio de Janeiro	1920	do	do	do	do	do	do	Do.
136	46271	De trepar D. Carlos	do	1920	do	do	do	Moderate	do	do	None.
137	46267	De trepar monteiga preto	do	1920	do	do	do	do	do	do	Severe.
138	46517	Enxofre	Para	1920	do	do	do	do	do	do	Moderate.
139	46509	Rajado	do	1920	do	do	do	do	do	do	Slight.
140	46514	Favinha	do	1920	do	do	do	do	do	do	Do.
141	46071	Manteiga	Santos	1920	do	do	do	Severe	do	do	Severe.
142	46276	do	Rio de Janeiro	1920	do	do	do	do	do	do	Do.
143	46254	Manteiga (dwarf type)	Sao Paulo	1920-1923	Slight	Severe	Slight	do	90	None	Slight.
144	46269	Manteiga amarillo	Rio de Janeiro	1920	No data	No data	None	Moderate	No data	No data	Severe.
145	46512	Mulatinho	Para	1920	do	do	do	do	do	do	Slight.
146	46275	do	Rio de Janeiro	1920	do	do	do	do	do	do	Severe.
147	46213	do	Sao Paulo	1920	do	do	do	do	do	do	Slight.
148	46255	do	do	1920	do	do	do	Severe	do	do	Do.
149	46064	Mulatinho claro	Santos	1920	do	do	do	do	do	do	Severe.
150	46065	Mulatinho escuro	do	1920	do	do	do	Moderate	do	do	Do.
151	46072	Pintado	do	1920	do	do	do	Severe	do	do	Moderate.
152	46513	Preto	Para	1920	do	do	do	do	do	do	Slight.
153	46214	do	Sao Paulo	1920	do	do	do	Moderate	do	do	Do.
154	46256	do	do	1920	do	do	do	Severe	do	do	Severe.
155	46278	do	Rio de Janeiro	1920	do	do	do	Moderate	do	do	Do.
156	46326	do	Rio Grande	1920	do	do	do	Severe	do	do	Slight.

[a] Resistant to anthracnose.

[b] Resistant to bacterial blight.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

BRAZIL—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
157	46215	Riscado	Sao Paulo	1920	No data	No data	None	Severe	No data	No data	Moderate.
158	46257	do	do	1920	do	do	do	Moderate	do	do	Severe.
159	46216	Roxo	do	1920	do	do	do	Very slight	do	do	Slight.
160	46510	Salmao	Para	1920	do	do	do	Moderate	do	do	Moderate.
161	46066	Vermelho (red bean)	Santos	1920	do	do	do	do	do	do	Slight.
162	46518	Vermelho	Para	1920	do	do	do	Severe	do	do	None.
163	46511	Viuva alegre	do	1920	do	do	do	Moderate	do	do	Slight.

CHILE

(Seed obtained through American Consular Service)

164	46195	Bayos	Antofagasta	1920	No data	No data	Slight	Moderate	No data	No data	Severe.
165	46196	Burritos	do	1920	do	do	do	Very slight	do	do	Do.
166	46197	Caballeros	do	1920	do	do	do	Severe	do	do	Do.
167	46198	Canarios	do	1920	do	do	do	Very slight	do	do	Do.
168	46199	Coscorones	do	1920	do	do	do	do	do	do	Slight.
169	46200	Frutillas	do	1920	do	do	do	do	do	do	Do.
170	46201	Ovalitos	do	1920	do	do	None	Very severe	do	do	Do.
171	46202	Trigulitos	do	1920	do	do	do	Moderate	do	do	Severe.
172	46229	Bayos	Cosechas	1920	do	do	do	Very slight	do	do	Moderate.
173	46230	Caballeros	do	1920	do	do	do	Severe	do	do	Do.
174	46231	Coscorones	do	1920	do	do	Slight	Moderate	do	do	Do.
175	46526	Small white beans	Punta Arenas	1920	do	do	None	Slight	do	do	Severe.
176	46527	Light brown beans	do	1920	do	do	do	Very slight	do	do	Do.

177	46528	White and yellowish white beans (mixed).	do	1920	No data	do	do	do	do	do	Do.
178	46529	Yellow to brown beans (mixed).	do	1920	do	do	do	do	do	do	Moderate
179	46530	Grayish brown beans	do	1920	do	do	do	do	do	do	Slight.
180	51701	Light tan pea beans	Santa Ines	1921	do	do	Severe	do	do	do	None.

COLOMBIA

181	46015	Rojo	Barranquilla	1920	No data	No data	None	Slight	No data	No data	Slight.
182	46016	De Santander	do	1920–1923	Severe	None	Severe	Severe	77	None	Very severe.
183	46142	Reddish brown, black mottled beans.	Medellin	1920	No data	No data	No data	Moderate	No data	No data	None.
184	46143	Reddish brown beans	do	1920	do	do	do	do	do	do	Do.
185	46144	Cinnamon brown beans	do	1920	do	do	do	Slight	do	do	Do.

CZECHOSLOVAKIA

(Seed from Arnost Bahlsen, Prague)

		Dwarf varieties									
186		Cukrová perlička	Prague	1923	No data	No data	Slight	Severe	No data	None	Slight.
187		Flageolet Chevrierovy	do	1923	do	do	Moderate	do	do	do	Do.
188		Flageolet Zlutolnski	do	1923	do	do	do	Moderate	do	do	None.
189		Holandské bílé	do	1923	do	do	Slight	Severe	do	do	Slight.
190		Mont D'or Zlutolnské	do	1923	do	do	Severe	Moderate	do	do	None.
191		Nejrannější černé	do	1923	do	do	Moderate	Severe	do	do	Do.
192		Nevyčerpatelné	do	1923	do	do	Severe	do	do	do	Severe.
193		Non Plus Ultra	do	1923	do	do	Moderate	Moderate	do	do	None.
194		Panonia	do	1923	do	do	Slight	do	do	do	Do.
195		Saxa	do	1923	do	do	Moderate	do	do	do	Do.
196		Vosková datle	do	1923	do	do	Very severe	do	do	do	Do.
197		Voskova (pole type)	do	1923	do	do	Severe	do	do	do	Do.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

ECUADOR

(Seed presented by F. W. Gooding, American consul general)

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
198	46340	Bayo	Guayaquil	1920	No data	No data	None	Slight	No data	None	Severe.
199	46348	Burro amarillo	do	1920	do	do	do	do	do	do	Do.
200	46349	Caballero	do	1920	do	do	do	do	do	do	Do.
201	46351	Cacique	do	1920	do	do	do	do	do	do	Moderate.
202	46350	Chalos	do	1920	do	do	do	Moderate	do	do	Severe.
203	46650	Chola or Colorados	do	1920	do	do	do	Severe	do	do	Do.
204	46344	Criollo	do	1920	do	do	do	do	do	do	Do.
205	46347	Panamito reforzado	do	1920	do	do	do	do	do	do	Do.

ENGLAND

		Dwarf varieties									
206		Canadian Express	Carter	1923	No data	No data	Slight	Severe	No data	None	None.
207		Canadian Glory, stringless	do	1923	do	do	Severe	Moderate	do	do	Do.
208		Canadian Wonder	Sutton	1921–1923	Moderate	Severe	do	Very severe	63	Severe	Severe.
209		*Canadian Wonder, selected*	do	1923	No data	No data	do	Severe	No data	20	Do.
210		Early Giant	do	1923	do	do	do	do	do	None	Moderate.
211		Early Prolific	Carter	1923	do	do	do	do	do	Severe	Slight.
212		Everbearing	Sutton	1921–1923	Severe	Very slight	do	Very severe	100	None	Severe.
213		Evergreen	do	1921–1923	do	Severe	do	Moderate	100	do	Do.
214		Fifty Days	Carter	1923	No data	No data	do	do	No data	do	None.
215		Forcing	Sutton	1921–1923	Moderate	Moderate	do	Very severe	78	do	Moderate.
216		Golden Butter	Carter	1923	No data	No date	Moderate	Severe	No data	do	Do.
217		Golden Wax Pod	Sutton	1923	do	do	do	do	do	do	Do.
218		Green Gem	do	1921–1923	Moderate	Moderate	do	do	100	do	Slight.

218	----------	Green Gem	----do----	1921–1923	Moderate	Moderate	----do----	----do----	100	----do----	Slight.
219	----------	Long Podded Negro	----do----	1921–1923	No data	Severe	Severe	----do----	80	Slight	Severe.
220	----------	Longsword, reselected	Carter	1923	Moderate	No data	----do----	----do----	No data	----do----	Slight.
221	----------	Magnum Bonum	Sutton	1921–1923	None	Severe	----do----	----do----	80	None	Do.
222	----------	Magpie	Carter	1923	No data	No data	----do----	Moderate	No data	----do----	Moderate.
223	----------	Monster Negro	Sutton	1921–1923	----do----	Severe	Slight	Severe	78	----do----	Slight.
224	----------	Ne Plus Ultra, selected	----do----	1923	----do----	No data	Severe	Moderate	No data	----do----	Moderate.
225	----------	Osborn Early Forcing	Carter	1923	----do----	----do----	----do----	Severe	----do----	----do----	Slight.
226	----------	Perfection	Sutton	1921–1923	Moderate	Moderate	----do----	----do----	----do----	----do----	Do.
227	----------	Plentiful	----do----	1921–1923	----do----	Severe	----do----	----do----	----do----	----do----	Moderate.
228	----------	Perpetual	Carter	1923	No data	No data	Very severe	Moderate	----do----	Severe	Do.
229	----------	Premier	Sutton	1923	----do----	----do----	Severe	----do----	----do----	Slight	Slight.
231	----------	Prolific Negro	----do----	1921–1923	Moderate	Severe	----do----	Severe	90	None	Moderate.
232	----------	Reliance	----do----	1921–1923	Slight	Moderate	Moderate	----do----	90	----do----	Do.
233	----------	Satisfaction	----do----	1921–1923	Moderate	----do----	----do----	----do----	67	----do----	Slight.
234	----------	Sunrise	Carter	1923	No data	No data	Severe	Moderate	No data	Moderate	Moderate.
235	----------	Superlative	Sutton	1921–1923	Moderate	Severe	Moderate	Severe	70	None	Slight.
236	----------	White Haricot	----do----	1921–1923	----do----	Moderate	Severe	Very severe	100	----do----	Severe.
237	----------	White Model	Carter	1923	No data	No data	Moderate	Moderate	No data	----do----	Do.
		Pole varieties									
238	----------	Earliest of All	Sutton	1923	No data	No data	Very severe	Moderate	No data	None	Moderate.
239	----------	July Climbing	Carter	1923	----do----	----do----	----do----	----do----	----do----	----do----	None.
240	----------	Mont D'Or, Golden Butter	----do----	1923	----do----	----do----	----do----	Very severe	----do----	----do----	Moderate.
241	----------	Princess of Wales	Sutton	1923	----do----	----do----	Very slight	Severe	----do----	----do----	None.
242	----------	Reselected	Carter	1923	----do----	----do----	Severe	Moderate	----do----	----do----	Severe.
243	----------	Tender and True	Sutton	1923	----do----	----do----	Slight	Severe	----do----	----do----	Do.

FRANCE

(Seed from Vilmorin-Andrieux et Cie, Paris)

		Dwarf varieties									
244	----------	Barbes nain	Paris	1921–1923	No data	Moderate	Moderate	Severe	89	Slight	Slight.
245	----------	*Beurre blanc nain*	----do----	1921–1923	None	Slight	Slight *	Very severe	75	50	Do.
246	----------	Beurre doré nain	----do----	1921–1923	No data	Severe	Very severe	Severe	75	Severe	Do.
247	----------	Beurre nain de Digoin	----do----	1921–1923	----do----	Very severe	Moderate	Moderate	90	----do----	Do.
248	----------	Beurre nain de tous les jours	----do----	1921–1923	----do----	----do----	Very severe	Severe	89	None	Do.
249	----------	Beurre nain du Mont-d'Or	----do----	1921–1923	----do----	Severe	Severe	----do----	78	----do----	Do.
250	----------	Beurre nain Gloire d'Olainville.	----do----	1921–1923	----do----	Very severe	Very severe	----do----	20	Moderate	Do.
251	----------	Beurre nain Merveille du Marché.	----do----	1921–1923	----do----	----do----	Severe	----do----	67	Severe	Severe.
252	----------	Beurre nain Plein le-Panier	----do----	1923	----do----	No data	Moderate	----do----	No data	None	Slight.
253	----------	Beurre nain sans rival	----do----	1921–1923	----do----	Severe	Very severe	----do----	11	Severe	None.
254	----------	Beurre noir nain à longue cosse.	----do----	1921–1923	----do----	Moderate	Severe	----do----	100	Moderate	Slight.

* Resistant to anthracnose.

* Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

FRANCE—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Dwarf varieties—Contd.									
255		Coco marbré nain	Paris	1921–1923	No data	No data	Moderate	Moderate	No data	None	Slight.
256		Comtesse de Chambord	do	1921–1923	do	Severe	Severe	Severe	71	do	Moderate.
257		d'Alger (beurre) noir nain	do	1921–1923	do	do	do	do	100	do	Severe.
258		De Bagnolet	do	1921–1923	do	do	do	do	50	Severe	Slight.
259		De Bagnolet à feuille d'Ortie.	do	1921–1923	do	do	do	do	100	None	Severe.
260		De Bagnolet vert	do	1921–1923	Severe	do	do	do	100	Moderate	Slight.
261		De Soissons nain	do	1921–1923	No data	Moderate	Moderate	do	75	Severe	Severe.
262		Du Bon Jardinier	do	1923	do	No data	do	do	No data	do	Slight.
263		Du Bouscat	do	1921–1923	do	Moderate	do	do	89	None	Moderate.
264		Du Perreux	do	1921–1923	do	Severe	Slight	Moderate	89	do	None.
265		Empereur de Russie	do	1921–1923	do	do	Moderate	do	75	do	Slight.
266		Extra-precoce de Fontenay	do	1921–1923	do	Very slight	Slight	do	100	Slight	Do.
267		Flageolet beurre (nain)	do	1921–1923	do	Severe	Severe	Severe	100	None	Do.
268		Flageolet blanc à longue cosse.	do	1921–1923	do	Moderate	Moderate	Moderate	89	do	Do.
269		*Flageolet blanc extra*	do	1921–1923	None	Very slight	Slight	Severe	100	70	Moderate.
270		Flageolet Chevrier	do	1921–1923	No data	Moderate	Moderate	do	86	Severe	Do.
271		Flageolet de Vitry blanc	do	1921–1923	do	do	do	Very severe	100	None	Slight.
272		Flageolet jaune ameliore	do	1921–1923	do	do	Very slight	Severe	67	100	Do.
273		Flageolet Merveille de France.	do	1921–1923	do	do	Slight	do	83	Slight	Severe.
274		Flageolet nain hâtif à feuille gaufrée.	do	1921–1923	do	Severe	do	Very severe	100	Moderate	Do.
275		Flageolet nain Triomphe des chassis.	do	1921–1923	do	Slight	do	Severe	89	None	Slight.

276		Flageolet noir	do	1921–1923	do	Severe	do	do	100	do	Do.
277		Flageolet Roi des verts	do	1921–1923	Very severe	Very slight	do	do	89	Severe	Moderate.
278		Flageolet rouge	do	1921–1923	No data	Very severe	Moderate	Very severe	100	None	None.
279		Flageolet rouge de Vitry	do	1921–1923	do	Moderate	None	Severe	100	do	Slight.
280		Flageolet très hâtif d'Etampes.	do	1921–1923	Severe	None	do	do	100	do	Do.
281		Gloire de Lyon	do	1921–1923	No data	Severe	Slight	Very severe	75	Severe	Do.
282		Gros vert hâtif	do	1921–1923	do	do	do	do	100	None	Do.
283		*Incomparable (H. express)*	do	1921–1923	Severe	Moderate	do	Slight [b]	100	do	Do.
284		Incomparable à grain vert	do	1921–1922	No data	Severe to moderate.	No data	Severe	100	No data	None.
285		Jaune cent-pour-un	do	1921–1923	do	Very slight	Slight	do	0	Severe	Do.
286		Jaune de la Chine	do	1921–1923	do	Slight	do	do	50	Slight	Slight.
287		Jaune du Canada	do	1921–1923	do	Very severe	Moderate	do	100	None	Moderate.
288		Le Bleu	do	1921–1923	do	do	do	Very severe	44	do	Slight.
289		L'Inépuisable	do	1921–1923	Severe	Very slight	Slight	Severe	22	Severe	Do.
290		Merveille de Paris	do	1921–1923	No data	Moderate	do	do	67	None	Do.
291		Metis (H. Eclipse)	do	1921–1923	Severe	Severe	Severe	do	100	Slight	Do.
292		Nain blanc hâtif sans parchemin.	do	1921–1923	No data	Moderate to none.	Moderate	do	100	None	Moderate.
293		Nain blanc quarantain	do	1921–1923	do	Moderate	Slight	Moderate	100	Slight	Slight.
294		Nain blanc Unique	do	1921–1923	Very severe	Slight	Severe	Severe	88	Severe	Moderate.
295		Nain de Lignereux	do	1921–1923	No data	Severe	Moderate	do	100	Moderate	Slight.
296		Nain jaune extra-hâtif	do	1921–1922	do	do	No data	do	90	No data	None.
297		*Nain Lyonnais à grain blanc*	do	1921–1923	Moderate	None	Slight	do	88	20 [a]	Slight.
298		Nain Lyonnais à très longue cosse.	do	1921–1923	do	do	Moderate	do	75	None	Do.
299		*Nain Mangetout extra-hâtif*	do	1921–1923	None	Very slight	Slight [a]	Moderate	70	do	Do.
300		Nain Mangetout Phenix	do	1923	No data	No data	Moderate	do	No data	do	Do.
301		Nain Parisien	do	1921–1923	do	Slight	Slight	do	56	Slight	Moderate.
302		Nain Roi des Beurres	do	1923	do	No data	Moderate	Severe	No data	Severe	Do.
303		Noir de l'Hermitage	do	1921–1923	do	Very severe	Slight	do	100	do	Slight.
304		Noir hâtif de Belgique	do	1921–1923	do	do	Very slight	Moderate	90	None	Do.
305		Predome nain	do	1921–1923	do	Severe to moderate.	Slight	Severe	86	do	Do.
306		Prince noir	do	1921–1923	do	Severe	Moderate	Very severe	100	do	Do.
307		Princesse nain à grosse cosse	do	1921–1923	do	do	Severe	do	100	Slight	Severe.
308		Rouge d'Orleans	do	1921–1923	do	do	Moderate	do	57	Severe	Slight.
309		Sabre nain (H. hâtif de Hollande).	do	1921–1923	Very severe	None	do	do	90	None	Very severe.
310		St. Esprit	do	1921–1923	No data	Severe	do	Severe	91	Slight	Slight.
311		Shah de Perse	do	1921–1923	do	Very severe	Severe	do	83	do	Do.
312		Suisse blanc (H. lingot)	do	1921–1923	do	do	Slight	do	79	Severe	Do.
313		Suisse rouge	do	1921–1923	do	do	Moderate	do	77	None	Do.
314		Surpasse tout	do	1923	do	No data	Severe	do	No data	Moderate	Do.
315		Très hâtif de Cholet	do	1921–1923	do	Severe	Moderate	do	100	None	Do.
316		Très nain precoce	do	1921–1923	do	Very severe	do	do	89	do	None.

[a] Resistant to anthracnose.

[b] Resistant to bacterial blight.

[c] Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

FRANCE—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties									
317		À rames extra-hâtif	Paris	1921–1923	Very severe	None	Very severe	Severe	100	Slight	Slight.
318		Avant-garde	do	1921–1923	No data	Severe to none	Moderate	Very severe	88	None	Moderate.
319		Beurre blanc à rames	do	1921–1923	None	Very severe	Very severe	Severe	100	do	Slight.
320		Beurre Couronne d'Or	do	1921–1923	Very slight	Severe	Slight	Very severe	57	do	Do.
321		Beurre du Mont-d'Or	do	1921–1923	No data	Very severe	Very severe	do	89	do	Moderate.
322		Beurre Roi des Mangetout	do	1921–1923	do	do	do	Severe	57	do	None.
323		Blanc géant sans parchemin.	do	1921–1923	Very severe	None	do	do	88	do	Severe.
324		Blanc grande Mangetout	do	1921–1923	do	do	Moderate	do	100	do	None.
325		*Coco bicolore du Pape*	do	1921–1923	Moderate	None	Slight	Slight [b]	86	do	Do.
326		Coco bicolore prolifique	do	1921–1923	No data	Very severe	Very severe	Severe	100	do	Do.
327		Coco blanc	do	1921–1923	do	None	Moderate	Moderate	100	do	Do.
328		Coco rose à rames	do	1921–1923	do	Very severe	Severe	Severe	89	do	Do.
329		D'Alger (beurre) noir	do	1921–1923	do	do	Very severe	do	67	do	Moderate.
330		De Liancourt	do	1921–1923	Very severe	Moderate	do	do	70	do	Slight.
331		De Sallandre amelioré	do	1921–1923	No data	Very severe	Slight	do	100	do	Severe.
332		De Soissons blanc à rames	do	1921–1923	do	Moderate	Severe	do	90	do	None.
333		*De Soissons vert à rames*	do	1921–1923	do	None	Moderate	do	20 [c]	do	Slight.
334		Flageolet rouge à rames	do	1921–1923	do	Very severe	Slight	Very severe	100	do	Moderate.
335		Jaune d'or à rames	do	1921–1923	do	do	Severe	Moderate	88	do	None.
336		Mangetout de la Vallée	do	1921–1923	Very severe	None	Very severe	Severe	100	do	Slight.
337		Mangetout de Saint-Fiacre	do	1921–1923	Moderate	Very severe	do	do	100	do	Do.
338		Mangetout de Saint-Fiacre blanc.	do	1921–1923	No data	Moderate	Slight	Moderate	100	do	Do.
339		Mangetout du Maine	do	1921–1923	do	Very slight	do	Severe	60	do	Do.
340		Mangetout sans fil à rames	do	1921–1923	do	Very severe	Severe	do	88	do	Do.
341		Nigard	do	1921–1923	Very severe	None	do	do	78	do	Do.
342		Phénomène à rames	do	1921–1923	do	Very slight	do	do	63	do	Do.

343		Prédome à rames	do	1921–1923	No data	Moderate to slight.	do	Moderate	100	do	Severe.
344		Princesse à rames	do	1921–1923	do	None	Slight	Severe	100	do	Do.
345		Quatre-à-quatre	do	1921–1923	Very severe	Severe	Moderate	do	78	do	Slight.
346		Rig	do	1923	No data	No data	do	do	No data	do	Do.
347		Rond blanc commun	do	1921–1923	Severe to slight.	None	Severe	do	89	do	Do.
348		Riz à rames	do	1921–1922	No data	Severe	No data	do	100	No data	No data.
349		Rouge de Chartres	do	1921–1923	do	Slight	Severe	do	100	None	Slight.
350		Sabre, à très grande cosse	do	1921–1923	Very severe	None	do	do	80	do	Severe.
351		*Zébré gris*	do	1921–1923	No data	Very severe	Slight	Slight [b]	0 [c]	do	Slight.

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		Dwarf varieties									
352		Flageolet oder Pariser, rote	Beck & Co	1921–1923	No data	No data	Moderate	Severe	No data	None	Slight.
353		Flageolet oder Pariser, weisse	do	1921	do	do	No data	do	do	No data	No data.
354		Hamburger Markt	Sprechelsen	1923	do	do	Very severe	do	do	None	Severe.
355		Hinrichs Reisen	Beck & Co	1921–1923	do	do	Moderate	do	do	do	Slight.
356		Kaiser Wilhelm	do	1921–1923	do	do	Severe	Very severe	do	do	Severe.
357		Krummschnabel	Haage u. Schmidt.	1923	do	do	Moderate	Severe	do	Severe	Slight.
358		Londoner Markt	do	1923	do	do	Slight	Moderate	do	None	Do.
359		Nordstern	do	1923	do	do	Very severe	Very severe	do	Severe	Severe.
360		Osborn's Treib	do	1923	do	do	Moderate	Severe	do	do	Moderate.
361		Prinzess, doppelte holland	Sprechelsen	1923	do	do	Severe	Moderate	do	None	Severe.
362		Saxa fadenlose	Schultz	1923	do	do	Moderate	do	do	100	None.
363		Schlachtschwert	Beck & Co	1921–1923	do	do	do	Severe	do	None	Do.
364		Wachs Dattel	do	1921–1923	do	do	do	Very severe	do	do	Slight.
365		Wachs Rekord	Sprechelsen	1923	do	do	Very severe	Moderate	do	do	None.
366		Zucker Butter Brech	Beck & Co	1921–1923	do	do	Moderate	Very severe	do	do	Severe.
		Pole varieties									
367		Don Carlos	do	1921–1923	do	do	do	do	do	do	None.
368		Flageolet Wachs, weissen bohnen	Schultz	1921–1923	do	do	Severe	do	do	do	Severe.
369		Hinrichs Reisen	Beck & Co	1921–1923	do	do	Very severe	Moderate	do	do	Slight.
370		Juli	Schultz	1921–1923	do	do	do	Severe	do	Slight	Do.
371		Meisterstuck	Haage & Schmidt.	1923	do	do	do	do	do	None	Do.
372		Mont d'Or, Wachs	Schultz	1921–1923	do	do	do	Very severe	do	do	Severe.
373		Mulstopper	Haage & Schmidt.	1923	do	do	do	Severe	do	do	Slight.
374		Ohnegleichen	do	1923	do	do	do	Moderate	do	do	None.
375		Phänomen	Beck & Co	1921–1923	do	do	Slight	Severe	do	do	Moderate.

[b] Resistant to bacterial blight.

[c] Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

GERMANY—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties—Continued									
376		Präsident	Schultz	1923	No data	No data	Moderate	Severe	No data	None	None.
377		Rheinische Schmalz grosse, weisse.	Beck & Co	1921–1923	do	do	Slight	Very severe	do	do	Slight.
378		Schlachtschwert, allergrösste, weisse.	Schultz	1921–1923	do	do	Very severe	do	do	do	Do.
379		Zehnwochen	Beck & Co	1921–1923	do	do	do	Severe	do	do	Very severe.

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(Seed presented by Direccion General de Agricultura, Guatemala City)

		Dwarf varieties									
380	53892	Colorado de gancho de suelo.	Chimaltenango	1922, 1923	None	Very severe	Slight	Severe	89	Moderate	Slight.
381	53839	Color de café	Quezaltenango	1922, 1923	Very severe	do	Severe	do	38	do	None.
382	53786–A	Cuarenteno negro	Ciudad Vieja, Sacatepequez.	1922	No data	No data	Slight	do	No data	No data	Do.
383	53793	Negro	San Martin, Chemaltenango, Chemaltenango	1922	do	do	do	Moderate	do	do	Do.

384	53776	Negro de vara	Sipacapa, San Marcos.	1922	do	do	None	Slight	do	do	Slight.
385	53784	Negro pequeño mata (mixed).	Cuilapa, Santa Rosa.	1922	do	do	do	Very severe	do	do	None.
386		(A) *Very small, dull black pea beans.*	do	1923	Very slight	None	Slight [a]	Moderate	74	50	Slight.
387		(B) *Smaller shiny black beans.*	do	1923	No data	No data	Moderate	do	No data	10 [a]	Do.
388	53822	Pinto negro sotero	Acatenango, Chemaltenango.	1922, 1923	Severe	Moderate	do	Severe	70	Severe	Do.
389	53840	Peruano de suelo (similar to 391).	Parramos, Chemaltenango.	1922, 1923	None	Very severe	Severe	do	100	do	Do.
390	53823	Pintillo	Pastorez, Sacatepequez.	1922	No data	No data	do	do	No data	No data	None.
391	53826	Pinto	San Lucas, Sacatepequez.	1922, 1923	None	Severe to moderate.	do	Moderate	70	Severe	Do.
392	53829	Pinto oscuro	Quezaltenango	1922, 1923	Severe	Severe	do	do	83	do	Slight.
393	53821	Riñon	Duenas, Sacatepequez.	1922, 1923	Moderate	Moderate	Slight	Severe	78	Slight	None.
394	53772	Very small, slender black beans.	San Sebastian, Huehuetenango.	1922, 1923	Very severe	None	Moderate	do	86	None	Severe.
395	56584	*Alubia (white kidney bean).*	Orig. from Zamora, Spain.	1923	No data	No data	Slight	Very slight [b]	No data	do	Slight.
		Pole varieties									
396	53800	Amarillo	San Lucas, Sacatepequez.	1922	do	do	do	Slight	do	do	Slight.
397	53801	do	San Juan A., Huehuetenango.	1922	do	do	Very severe	Severe	do	do	None.
398	53803	do	Ixtapacal San Rafael, San Marcos.	1922	do	do	Slight	Slight	do	do	Do.
399	53804	Amarillo de milpa	San Martin, Chimaltenango.	1922	do	do	do	do	do	No data	Slight.
400	53880	Blanco	San Mateo, Sacatepequez	1922	do	do	None	do	do	do	None.
401	53889	Blanco de enredo	La Candelaria, Barillas, Huehuetenango.	1922	do	do	do	do	do	do	Slight.
402	53876	Blanco de suelo	Camalapa, Chimaltenango.	1922	do	do	Slight	do	do	do	Very severe.

[a] Resistant to anthracnose

[b] Resistant to bacterial blight.

[c] Resistant to bacterial wilt

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

GUATEMALA—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties—Continued									
403	53874	Blanco de vara	Santa Maria de J., Sacatepequez.	1922	No data	No data	Slight	Severe	No data	No data	Severe.
404	53875	*Blanco de vara*	San Rafael, San Marcos.	1922, 1923	None	None	Very slight [a]	do	80	10 [a]	Slight.
405	53883	Blanco enredador	Chimaltenango	1922	No data	No data	None	Slight	No data	No data	Do.
406	53886	Blanco lecandor	Parramos, Chimaltenango.	1922	do	do	do	do	do	do	Severe.
407	53887	Colima	San Rafael, San Marcos.	1922	do	do	do	do	do	do	Slight.
408	53781	Colorado	San Andres C., Sacatepequez.	1922, 1923	Moderate	None	Slight	Moderate	89	90	Moderate.
409	53888	Colorado camalapa enredador.	Chimaltenango.	1922	No data	No data	None	do	No data	No data	Severe.
410	56583	De Mantua (dwarf type), originally from Valencia, Spain.	Guatemala City.	1923	do	do	Severe	do	do	None	Slight.
411	53786–B	Cuarenteno negro	Ciudad Vieja, Sacatepequez.	1922	do	do	None	Slight	do	do	Do.
412	53795	De riego mateado	Aguacatan, Huehuetenango.	1922, 1923	Severe	Severe to none	Severe	Severe	100	Slight	Do.
413	53792	*De sarco*	Zacualpa, Quiche.	1922, 1923	None	None	Slight [a]	Moderate	100	30 [a]	Do.
414	53814	Gato enredador	Patzum, Chi-	1922	No data	No data	Severe	Slight	No data	No data	Do.

414	53814	Gato enrededor	Patzum, Chimaltenango.	1922	No data	No data	Severe	Slight	No data.	No data	Do.
415	53838	Ixcaco enrededor	Parramos, Chimaltenango.	1922	do	do	Slight	do	do	do	Do.
416	53816	Kinak-Shak	Santiago, Saniora, Sacatepequez.	1922	do	do	do	Severe	do	do	Severe.
417	53791	Negro	Vainamorada, Chimaltenango, Chimaltenango.	1922	do	do	do	Slight	do	do	Slight.
418	53766	do	Santa Catarina B., Sacatepequez.	1922	do	do	None	Severe	do	do	None.
419	53778	Negro colas enrededor	Patzum, Chimaltenango.	1922	do	do	do	Slight	do	do	Slight.
420	53787	Negro cuarenteno	San Pedro La Laguna, Solola.	1922	do	do	do	do	do	do	Do.
421	53789	Negro de mata	Barillas, Huehuetenango.	1922, 1923	Moderate	None	Slight	Severe	77	None	Do.
422	53783	Negro de milpa	San Martin, Chimaltenango.	1922	No data	No data	None	Slight	No data.	No data	Do.
423	53774	Negro de Suelo	San Andres C., Sacatepequez.	1922	do	do	do	do	do	do	Do.
424	53775	*Negro de vara*	San Rafael, San Marcos.	1922, 1923	Very slight	None	Slight *	Severe	100	100	Do.
425	53773	Negro enrededor	Chimaltenango.	1922	No data	No data	do	Moderate	No data.	No data	None.
426	53770	do	Barillas, Huehuetenango.	1922, 1923	do	do	do	Very severe	do	None	Moderate.
427	53771	Negro enrededor nebaj	Quiche	1922	do	do	Severe	Slight	do	No data	Slight.
428	53777	Negro mateado	Aguacatan	1922	do	do	None	do	do	do	None.
429	53785	Negro pequeño	Japalmico, San Marcos.	1922, 1923	Severe to slight.	None	Slight to moderate.	Severe	71	70	Severe.
430	53873	Pequeño café	Tajumulco, San Marcos.	1922	No data	No data	Slight	Slight	No data.	No data	Do.
431	53832	Piato Lengua de vaca	San Martin J., Chimaltenango.	1922	do	do	Severe	do	do	do	Slight.
432	53872	Piloy	Xenacoj, Sacatepequez.	1922	do	do	do	Severe	do	do	Do.
433	53807	Pilique colorado	Senacoj, Sacatepequez.	1922, 1923	Moderate	None	Slight	Slight to moderate.	90	50	Do.
434	53834	Pinto	San Mateo Ma, Sacatepequez.	1922	No data	No data	Severe	Slight	No date.	No data	Severe.

* Resistant to anthracnose.

* Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

GUATEMALA—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties—Continued									
435	53831	Pinto de vara (mixed)	Neuvo Progreso, San Marcos.	1922	No data	No data	Slight	Moderate	No data	No data	None.
436		(A) "Vara" type, small plump purple, stippled, with black stripes.	do	1923	Very severe	Severe	Moderate	Very severe	80	None	Slight.
437		(B) Long, slender, black seed type.	do	1923	do	do	Slight	Severe	100	do	Moderate.
438	53830	Pinto enrededor	Lemon Salenor, Chiantha.	1922	No data	No data	None	do	No data	No data	Very severe.
439	53828	Retinto del Suelo	Jutiapa	1922, 1923	Severe	Slight	Moderate	Moderate	60	None	Severe.
440	53837	Rosado enrededor	do	1922, 1923	Very severe	Moderate to none.	Severe	do	90	65	Slight.
441	53825	Sardo	San Mateo Ma, Sacatepequez.	1922	No data	No data	Slight	Severe	No data	No data	Do.
442	53820	Varitas	San Antonio A. C., Sacatepequez.	1922, 1923	Severe to slight.	None	do	do	89	None	Severe.
443	53764	Small black pea beans	Santo Tomas, Chichacastenango, Quiche	1922	No data	No data	None	Slight	No data	No data	Slight.

444	53765	Large black pea beans	San Antonio S., San Marcos.	1922	do	do	do	Very slight	do	do		Do.
445	53767	Very small, flat black beans	San Miguel, Quiche.	1922	do	do	do	do	do	do		None.
446	53768	do	San Pedro las H., Sacatepequez.	1922	do	do	do	do	do	do		Slight.
447	53769	Small, flat black beans	San Pedro La Laguna, Solola.	1922	do	do	do	do	do	do		None.
448	53794	Very small, flat black beans.	Huehuetenango.	1922	do	do	Severe	Moderate	do	do		Slight.
449	53805	Small, black and tan beans (mixed).	Chimaltenango.	1922	do	do	Slight	Severe	do	do		None.
450	53782	Round, black, red, and tan beans (mixed).	Chimaltenango, Chimaltenango.	1922	do	do	do	Slight	do	do		Do.
451	53808	*Small, red kidney beans*	Aguacatan, Huehuetenango.	1922, 1923	None	None	Very slight[a]	do.[b]	88	40		Very severe.
452	53815	Large, chestnut-brown pea beans.	San Sebastian, Huehuetenango.	1922	No data	No data	Severe	Moderate	No data	No data		Slight.
453	53827	Mottled tan kidney beans with dark stripes.	Chimaltenango	1922	do	do	do	Severe	do	do		Severe.
454	56582	*Light tannish-pink beans*	Originally from Mexico.	1923	do	do	do	Very slight[b]	do	None		Very severe.
455	53817	*White pea beans*	Colotenango, Huehuetenango.	1922, 1923	Very slight	None	Very slight[a]	Moderate	100	10[c]		Severe.
456	53842	Small white kidney beans	Unknown	1922	No data	No data	Slight	Severe	No data	No data		Very severe.
457	53877	White pea beans	San Pedro La Laguna, Solola.	1922	do	do	Severe	Slight	do	do		Slight.
458	53878	do	do	1922	do	do	do	do	do	do		Severe.
459	53882	Small white pea beans	Acatenango, Chimaltenango.	1922	do	do	Slight	do	do	do		Slight.
460	53884	Small white marrow	Zaragoza, Chimaltenango.	1922	do	do	do	Severe	do	do		None.
461	53885	do	Itzapa, Chimaltenango.	1922	do	do	None	Slight	do	do		Slight.
462	53890	White marrow	San Antonio S., San Marcos.	1922	do	do	do	do	do	do		Do.
463	56583	Large white marrow, Bahama beans.	Guatemala City.	1923	do	do	do	Very severe	do	None		None.

[a] Resistant to anthracnose. [b] Resistant to bacterial blight. [c] Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

HOLLAND

(Seed from Sluis & Groot, Enkhuizen)

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms						
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection	Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
		Dwarf varieties									
464		Best of All, speckled seeded, stringy.		1923	No data	No data	None	Moderate	No data	None	Slight.
465		Best of All, speckled seeded, stringless.		1923	do	do	Slight	do	do	do	Do.
466		Best of All, white seeded, stringy.		1923	do	do	do	do	do	do	Very severe.
467		Best of All, white seeded, stringless.		1923	do	do	None	do	do	do	Slight.
468		Dark Dun or Liver Color, stringy.		1923	do	do	Slight	do	do	do	Do.
469		Delicata, stringless		1923	do	do	do	do	do	do	Very severe.
470		Dutch Middle Broad Longpod, stringy.		1923	do	do	Moderate	Severe	do	do	Do.
471		Early White Farming, stringy.		1923	do	do	Slight	do	do	Slight	Severe.
472		Extra Large Sword or Caseknife, stringy.		1923	do	do	Moderate	do	do	None	Very severe.
473		Extra Large Sword or Caseknife, stringless.		1923	do	do	do	do	do	do	Do.
474		North Star		1923	do	do	do	do	do	do	Moderate.
475		Pale Dun or Cream Color, stringy.		1923	do	do	do	Moderate	do	do	Slight.
476		Perfect, dwarf white early, stringless.		1923	do	do	Slight	Severe	do	do	Very severe.
477		Princess White, stringy		1923	do	do	Very slight	Very severe	do	Moderate	Severe.

478		Princess White, stringless		1923	do	do	Slight	Severe	do	None	Very severe.
479		Transvalian, stringless		1923	do	do	do	do	do	do	Do.
480		Volger Edible Podded White, stringless.		1923	do	do	Very severe	Very severe	do	Slight	Do.
		Pole varieties									
481		Abundance Dutch Sword, stringy.		1923	No data	No data	Very severe	Severe	No data	None	Severe.
482		Avant Garde, stringy		1923	do	do	do	do	do	do	Do.
483		Perfection, finest white pearl, stringless.		1923	do	do	Moderate	do	do	do	Moderate.
484		President Roosevelt, stringless.		1923	do	do	Very severe	do	do	do	Severe.
485		Princess Small White, stringless.		1923	do	do	Moderate	do	do	do	Do.
486		Vancelots Giant White Princess, stringless.		1923	do	do	Severe	do	do	do	Do.

HONDURAS

(Seed from Bally Tree Falls, British Honduras)

		Pole varieties									
487		De Milpa		1922	No data	No data	Slight	Slight	No data	No data	Slight.
488		do		1922	do	do	None	No data	do	do	None.
489		Pelon (small yellow)		1922	do	do	do	None	do	do	Do.

ITALY

(Seed from Fratelli Ingegnoli, Milan)

		Dwarf varieties									
490		Borlotto screziato O Regina.		1923	No data	No data	Severe	Moderate	No data	Slight	Slight.
491		Butirro bianco commune		1923	do	do	do	do	do	None	Very severe.
492		Cento per uno		1923	do	do	do	Severe	do	do	Slight.
493		Da Cornetto giallo		1923	do	do	Moderate	Moderate	do	do	Do.
494		*Meraviglia di Lione*		1923	do	do	do	Slight [b]	do	Slight	Do.
495		Nostrano Aquila		1923	do	do	do	Moderate	do	Severe	Do.
496		Quarantino bianco, "Cannellino."		1923	do	do	Slight	do	do	None	Do.

[b] Resistant to bacterial blight.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

ITALY—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Dwarf varieties—Contd.									
497	.....	Quarantino giallo-feltrino	.....	1923	No data	No data	Moderate	Severe	No data.	Moderate	Slight.
498	.....	Rognone di Gallo	.....	1923	do	do	Severe	do	do	Severe	Do.
499	.....	*Varesotto*	.....	1923	do	do	Moderate	Slight [b]	do	None	Very severe.
		Pole varieties									
500	.....	Bianco piatto	.....	1923	No data	No data	Slight	Slight	No data	None	Slight.
501	.....	Borlotto di Brianza	.....	1923	do	do	Severe	Moderate	do	do	None.
502	.....	Borlotto di Vigevano screziato.	.....	1923	do	do	Very severe	do	do	do	Do.
503	.....	Burro rampicante à cornetto giallo.	.....	1923	do	do	do	do	do	do	Do.
504	.....	Butirro bianco Prolifico	.....	1923	do	do	do	do	do	do	Do.
505	.....	Del Re	.....	1923	do	do	Severe	do	do	do	Do.
506	.....	Fenomeno	.....	1923	do	do	Slight	do	do	do	Do.
507	.....	Grigio tondo nostrano	.....	1923	do	do	Very severe	Severe	do	do	Do.
508	.....	Testa di Frate	.....	1923	do	do	Moderate	Moderate	do	do	Slight.
					JAPAN						
		Dwarf varieties									
509	.....	Aka Tsurunashi Ingen	Oriental Seed Co.	1921-1923	No data	No data	Slight	Severe	No data	None	None.
510	.....	Kintoki Ingen	do	1921-1923	do	do	Moderate	do	do	do	Moderate.
511	.....	Osaya Benkoi Ingen	do	1921-1923	do	do	Very severe	do	do	do	Slight.

512		Sarasa Ingen	do	1921–1923	do	do	Severe	do	do	do	Do.
513		Stringless Wax pod	do	1921	do	do	None	do	do	No data	None.
		Pole varieties									
514		Chufuku	M. F. Barrus, Cornell University.	1920	No data	No data	None	Severe	No data	No data	Severe.
515		Chunagazura	Direct importation.	1923	do	do	Moderate	Moderate	do	None	Moderate.
516		Chunagazura	M. F. Barrus, Cornell University.	1920	do	do	None	Severe	do	No data	Slight.
517		Chu Tenashi	do	1920	do	do	do	do	do	do	Severe.
518		Diafuku, large white butter.	do	1920	do	do	do	do	do	do	Moderate.
519		Kintoki (Low's Champion)	do	1920	do	do	do	do	do	do	Slight.
520		Kotenashi, small white pea	do	1920	do	do	do	do	do	do	Severe.
521		Kumamoto Ingen	do	1920	do	do	do	do	do	do	Do.
522		Muro Ingen	do	1920	do	do	do	do	do	do	Very severe.
523		Nagazura (Goddard)	Direct importation.	1923	do	do	Moderate	Moderate	do	None	None.
524		Naga Usura, mottled kidney.	M. F. Barrus, Cornell University.	1920	do	do	None	do	do	No data	Slight.
525		Osaya Dais Ingen	Oriental Seed Co.	1921–1923	do	do	Slight	Severe	do	None	Severe.
526		Otafuku, white	do	1921	do	do	None	do	do	No data	Slight.
527		Shiro Tsurunashi	do	1921	do	do	do	Moderate	do	do	Do.
528		*Suzunari Ingen*	do	1921–1923	do	do	Slight	Slight [b]	do	None	None.
529		Yatsubusa, black seed	do	1921–1923	do	do	Moderate	Severe	do	do	Severe.
530		Yatsubusa, brown seed	do	1923	do	do	Severe	Moderate	do	do	None.
531		Yatsubusa, white seed	do	1921–1923	do	do	Moderate	Severe	do	do	Very severe.

JAVA

(Seed presented by C. J. J. Van Hall)

		Pole variety									
532		Katjang merah	Departement Landbouw.	1923	Moderate	Moderate	None	Moderate	No data	None	Slight.

[b] Resistant to bacterial blight.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

KENYA COLONY, AFRICA

(Seed collected by H. L. Shantz)

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms						
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection	Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
		Dwarf varieties									
533	51528	Red beans	Meru District, Nairobi.	1921	No data	No data	None	Severe	No data.	No data.	Slight.
534	52205	Brown beans with marroon stripes and flecks.	Kisumu	1921	do	do	Severe	Very severe	do	do	Do.
535	52206	Small, shiny, and dull black beans (similar to Nos. 573 and 649 from Urundi).	do	1921–1923	Very severe	Very slight	do	Severe	100	None	Very severe.
536	52207	Large, narrow, red beans	do	1921	No data	No data	None	Very severe	No data.	No data.	Do.
537	52209	Long, narrow, light brown beans with darker stripes and flecks.	do	1921	do	do	do	Moderate	do	do	None.

MEXICO

(Seed presented by E. J. Hands, Dos Cebezos, Ariz.)

		Pole variety									
538	53532	Large tan beans with chocolate-colored stripes.	Chihuahua	1922	No data	No data	None	None	No data.	No data.	Severe.

PERU

(Seed presented by Luis Roos & Co., Callao-Lima)

		Pole varieties									
539	46154	Panamitos	Pacasmayo	1920–1923	Very severe	Severe	Moderate	Severe	78	None	Severe.
540	46155	Negros	Chincha	1920	No data	No data	None	Slight	No data.	No data	Do.

RUSSIA

(Seed presented by J. Palibin, Director Botanic Garden, Batum, Transcaucasia)

		Pole varieties									
541	51079	*Short, thick beans with maroon splotches on white background.*	Kutais district.	1921	No data	No data	None	Slight [b]	No data.	No data	None.
542	51080	Light-tan beans with lilac spots.	Georgia district.	1921	do	do	Severe	Severe	do	do	Slight.
543	51081	Dark-tan beans with lilac spots.	do	1921	do	do	do	Moderate	do	do	Do.
544	51082	*Grayish-tan beans with dark ring around hilum.*	do	1921	do	do	Moderate	Slight [b]	do	do	None.
545	51083	*Brownish-tan beans with dark ring around hilum.*	do	1921	do	do	Slight	do [b]	do	do	Slight.
546	51084	Long, slender, dark-red beans.	do	1921	do	do	do	Moderate	do	do	Do.

UGANDA

(Seed collected by H. L. Shantz)

		Dwarf varieties									
547	52189	Short lavender beans with dark ring.	Misindi	1921–1923	Severe	Severe	Severe	Moderate	86	Slight	Severe.
548	52190	Short drab beans with dark ring.	do	1921–1923	No data	No data	Slight	do	No data.	Moderate	None.
549	52191	(A) *Short light brown beans with dark ring.*	do	1921–1923	None	Severe	Moderate	Slight [b]	84	do	Severe.
550		(B) Long, kidney-shaped dark brown beans with dark ring.	do	1923	No data	No data	Slight	Moderate	No data.	None	Slight.
551	52192	*Short light green beans with brown ring.*	do	1921–1923	Very slight	None	None [a]	do	62	20 [c]	None.
552	52193	*Short greenish-tan beans with brown ring.*	do	1921–1923	do	do	do. [a]	Severe	80	60	Slight.

[a] Resistant to anthracnose. [b] Resistant to bacterial blight. [c] Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

UGANDA—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms						
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection	Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
		Dwarf varieties—Contd.									
553	52194	Long yellowish-tan beans with dark ring.	Misindi	1921–1923	Very slight	Severe	Slight	Severe	100	Severe	Very severe.
554	52196	Large long red beans	do	1921–1923	None	Moderate	Moderate	Moderate	59	100	Slight.
555	52197	Large long red beans (probably identical with above).	do	1921–1923	do	Severe	Slight	do	87	90	Do.
556	52198	*Small light pink beans with stripes and flecks of maroon.*	do	1921	No data	No data	do	Slight [b]	No data	No data	None.
557	52199	Small flat dull-tan beans	do	1921–1923	Very severe	Moderate	Severe	Moderate	63	Moderate	Slight.
		Pole varieties									
558	52186	Small black beans	Misindi	1921	No data	No data	None	Moderate	No data	No data	None.
559	52187	Long maroon beans with cream flecks.	do	1921	do	do	do	do	do	do	Do.
560	52188	Blue and gray stippled kidney beans with dark ring around hilum.	do	1921–1923	Very severe	Severe	Severe	Severe	90	do	Slight.
561	52195	Long tan beans with dark-brown ring.	do	1921	No data	No data	None	Moderate	No data	No data	None.
562	52200	(A) Light-tan beans with dark purple stripes.	do	1921–1923	Very severe	Very severe	Very severe	do	100	None	Slight.
563		(B) Gray beans with olive green stripes and brown ring.	do	1923	do	Moderate	Severe	Severe	100	do	Severe.
564		(C) Gray beans with scattered brown stippling and brown ring.	do	1923	do	do	No data	No data	100	No data	No data.

565	52201	*Long cream beans with dark red mark through hilum.*	do	1921	No data	No data	Severe	Slight [b]	No data	do	None.
566	52202	Long, broad white beans	do	1921	do	do	Slight	Severe	do	do	Do.
567	52203	Small, short white beans	do	1921–1923	Very severe	Slight	Very severe	Very severe	91	None	Severe.

URUGUAY

(Seed presented by D. Basso, through American Consular Service)

568	46164	De la Regna (originally from Italy).	Montevideo	1920	No data	No data	None	Moderate	No data	No data	Slight.
569	46165	Aguila (originally from Italy).	do	1920	do	do	do	Severe	do	do	Do.

URUNDI, AFRICA

(Seed collected by H. L. Shantz)

		Pole varieties (except Nos. 574 and 615)									
570	50251	Somewhat flattened white pea bean.	Usumbura	1921–1923	Very severe	None	Moderate	Moderate	93	None	Very severe.
571	50252	Large greenish yellow kidney beans.	do	1921	No data	No data	None	Severe	No data	No data	None.
572	50253	Short light brownish beans	do	1921–1923	None	Severe	Moderate	do	83	70	Slight.
573	50254	(A) Small slender black kidney beans (similar to Nos. 535 and 649 from Kenya).	do	1921–1923	Severe	None	Severe	do	80	None	Severe.
574	.....	(B) Small short sooty-brown mixture from above.	do	1923	Very severe	do	Moderate	do	100	do	Very severe.
575	50256	Light yellow beans with dark stripes.	do	1921	No data	No data	Slight	Moderate	No data	No data	Slight.
576	50257	Reddish beans with dark stripes.	do	1921	do	do	None	do	do	do	Do.
577	50259	*Large flat purple-mottled beans with dark ring.*	do	1921–1923	Very severe	do	Moderate	Slight [b] to moderate.	90	Slight	Moderate.
578	50260	*Purple, red-mottled beans*	do	1921	No data	do	None	Slight [b]	No data	No data	None.
579	50261	Deep-red beans	do	1921	do	do	do	Severe	do	do	Do.
580	50262	Deep-purple beans	do	1921	do	do	do	Moderate	do	do	Do.
581	50263	Gray beans	do	1921	do	do	do	do	do	do	Do.
582	50264	Short, plump, reddish beans with light-purple stripe.	do	1921–1923	None	Severe	Severe	do	70	80	Very severe.

[b] Resistant to bacterial blight.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

URUNDI, AFRICA—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties (except Nos. 574 and 615)—Continued									
583	50265	Long red beans with light-tan mottling (probably identical with No. 613).	Usumbura	1921–1923	None	Very severe	Severe	Very severe	62	Slight	Slight.
584	50266	(A) Long, flat, light-pink beans.	do	1921–1923	do	Severe	Moderate	Moderate	89	100	Do.
585		(B) Large, long, blue beans with tan splotches.	do	1923	do	do	Slight	do	51	None	Moderate.
586	50267	(A) Large, long purplish-brown, purple-speckled beans.	do	1923	do	do	Severe	do	100	100	Slight.
587		(B) Small light-gray beans with brown-stippled ring.	do	1923	Severe	None	Moderate	Severe	100	None	Very severe.
588	50845	Short, thick, light-brown beans with greenish stripes.	Nyanza	1921–1923	None	Severe	Severe	do	67	90	None.
589	50846	*Long, flat, brown beans*	do	1921	No data	No data	None	Slight [b]	No data	No data	Do.
590	50847	*Short, thick, chocolate-colored beans.*	do	1921–1923	None	Very severe	Very severe	Severe	81	10 [c]	Slight.
591	50848	(A) Short, thick, brownish-tan with darker ring.	do	1921–1923	Severe	do	Severe	do	79	100	None.
592		(B) Small, bluish-tan mottled beans.	do	1923	do	Slight	do	Moderate	83	50	Slight.
593	50849	Large, blue-tan mottled beans with dark blue stripes (slight segregation).	do	1921–1923	Slight	Severe	Moderate	Severe	77	80	Do.

594	50850	*Short, plump, Sudan-brown beans (similar to No. 572, slight segregation).*	do	1921–1923	None	None	Very slight [a]	Slight [b]	100	100	None.
595	50851	Short, plump Brussels-brown beans (similar to Nos. 572 and 594).	do	1921–1923	Very severe to none.	Very severe to none.	Moderate	Moderate	94	80	Slight.
596	50852	Long, plump, dark-tan beans (similar to No. 591, much segregation).	do	1921–1923	No data	No data	Slight	Severe	No data.	100	Do.
597	50853	*Purple-chocolate colored marrow beans (probably identical with 633).*	do	1921–1923	None	None	Very slight [a]	Slight to moderate. [b]	83	90	None.
598	50854	Rich tan-colored bean with mottled surface.	do	1921–1923	do	Severe	Moderate	Severe	90	None	Slight.
599	50855	Small wine-red kidney beans with dark stripes (similar to No. 117 from Belgian Congo).	do	1921–1923	do	Very severe	do	do	81	82	Do.
600	50856	*Very small, plump olive-green beans with tan mottling.*	do	1921–1923	Very severe	do	Severe	do	90	30 [c]	None.
601	50857	Yellow beans with brown markings.	do	1921	No data	No data	None	do	No data.	No data	Do.
602	50859	(A) Finely stippled wine-red kidney beans with black stripes.	do	1921–1923	None	Severe	Moderate	Moderate	100	None	Severe.
603		(B) Finely stippled lavender kidney beans with olive stripes.	do	1923	No data	No data	None	do	No data.	do	Slight.
604	50860	Very small flat, tan beans with black stripes.	do	1921–1923	Very severe	Slight	Very severe	Severe	83	do	Severe.
605	50861	(A) Light-tan beans with light olive-green stripes.	do	1921–1923	None	Severe	Slight	do	89	do	Slight.
606		(B) Tan kidney beans with olive stripes.	do	1923	do	do	Moderate	Moderate	83	do	Do.
607		(C) *Long, finely stippled, blue-tan beans with black stripes (similar to No. 593).*	do	1923	do.	Very slight [a]	No data	No data	89	No data	No data.
608	50862	*Light kidney-shaped beans with violet to blue stripes (similar to No. 118 from Belgian Congo).*	do	1921–1923	do	Very severe	Moderate	Severe	100	30 [c]	Slight.
609	50863	Deep yellowish brown beans with black stripes.	do	1921–1923	do	do	Slight	Moderate	67	None	Do.
610	50864	Flat, pinkish kidney beans with purple stripes.	do	1921–1923	do	do	Severe	do	95	65	Do.
611	50865	Small, plump pinkish beans with purple stripes.	do	1921–1923	do	Severe	do	do	78	55	Do.

[a] Resistant to anthracnose. [b] Resistant to bacterial blight. [c] Resistant to bacterial wilt.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

URUNDI, AFRICA—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one or more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties (except Nos. 574 and 615)—Continued									
612	50866	Long, flat pink beans with red stripes or mottling (similar to No. 114 from Belgian Congo).	Nyanza	1921–1923	Very severe	Very severe	Severe	Severe	91	None	Very severe.
613	50867	Long, red beans with light-tan mottling (dwarf) (probably identical with No. 583).	do	1921–1923	None	do	do	Very severe	67	Severe	Slight.
614	50869	Small, short, deep-red beans.	do	1921	No data	No data	None	Moderate	No data	No data	None.
615	50870	*Short, thick, deep wine-colored beans*	do	1921	do	do	do	Very slight [b]	do	do	Slight.
616	50871	Long, flat, purplish-tan beans.	do	1921	do	do	do	Severe	do	do	None.
617	50872	(A) *Red kidney beans (probably contain some hybrid seed).*	do	1921–1923	Very slight	Slight	Slight [a]	Moderate	83	100	Do.
618		(B) *Broad, flat, drab-colored beans (probably contain some hybrid seeds).*	do	1923	None	Very slight	do.[a]	Severe	89	100	Do.
619	50873	(A) *Small, lavender mottled beans with dark ring around hilum.*	do	1921–1923	Very slight	None	None [a]	Moderate	100	None	Slight.
620		(B) Small, bluish-black beans.	do	1923	do	Very slight	Moderate	do	83	70	Do.
621	50875	*Reddish mottled beans*	do	1921	No data	No data	None	Slight [b]	No data	No data	Do.
622	50876	Long, flat, lavender-purple mottled beans.	do	1921–1923	Severe to none.	Severe to none.	Very severe	Severe	100	100	Slight.

623	50877	(A) Small, slender, grayish-tan beans with bluish-black mottling (much segregation).	do	1921–1923	Severe	Slight	Slight	do	67	70	None.
624		(B) Flat, olive-brown beans with tan mottling.	do	1923	do	No data	Moderate	Moderate	100	50	Do.
625	50878	Long, mottled reddish-lavender beans with dark ring (similar to No. 630).	do	1921–1923	None	do	Slight	Severe	80	None	Slight.
626	50879	(A) *Blue and gray stippled kidney beans (similar to No. 560 from Uganda).*	do	1921–1923	do	Severe	Severe	Very slight [b]	100	do	Do.
627		(B) *Flat, blue-tan mottled beans.*	do	1923	do	Very slight	Very slight [a]	Moderate	80	do	Do.
628	50880	Short, plump, tan-purple stippled beans with dark ring.	do	1921–1922	No data	No data	None	Severe	No data.	No data	None.
629	50881	Small, purple-gray mottled beans with dark ring.	do	1921–1923	None	Severe	Moderate	Moderate	89	None	Severe.
630	50882	Long, mottled lavender beans with brown ring (similar to No. 625).	do	1923	do	Very severe	do	do	100	do	Do.
631	50883	*Small, flat, yellowish-tan mottled beans (some segregation).*	do	1921–1923	do	Very slight	Slight [a]	Severe	89	50	Do.
632	50884	Long, brown-mottled beans with dark ring.	do	1921–1923	do	Very severe	Moderate	do	100	None	Do.
633	50885	*Purple - chocolate - colored marrow beans (probably identical with No. 597).*	do	1921–1923	do	None	None [a]	Moderate	94	85	Slight.
634	50886	(A) Small, flat, maroon beans.	do	1921–1923	do	Severe	Moderate	Severe	100	None	Do.
635		(B) *Small, flat, pink beans.*	do	1922–1923	No data	None	do	Slight [b]	No data.	do	Do.
636		(C) *Small gray beans with red stippling on end or back.*	do	1922–1923	Very slight	Severe	Slight	do.[b]	89	do	Do.
637	50887	Short, plump, chocolate-brown beans (similar to No. 638).	do	1921–1923	None	Very severe	Severe	Severe	73	70	Do.
638	50888	(A) *Light-chocolate-brown marrow beans (similar in plant characters to No. 635).*	do	1921–1923	do	None	Very slight [a] to none.	Moderate	81	50	None.
639		(C) Small, flat, dark-tan beans.	do	1923	No data	Slight	Slight	do	70	65	Slight.
640	50889	Long, plump, greenish-yellow beans with dark ring around hilum.	do	1921–1923	Moderate	Very severe	do	Very severe	79	None	Very severe.
641	50891	Small, nearly round, straw-colored beans.	do	1921–1923	Very severe	No data	do	do	90	do	Severe.
642	50892	Large, white kidney beans (very late).	do	1921–1923	do	Severe	Severe	Severe	75	do	Very severe.

[a] Resistant to anthracnose.

[b] Resistant to bacterial blight.

TABLE II.—*Summarized data on the reaction of some American and foreign varieties of beans to greenhouse and field inoculations*—Contd.

URUNDI, AFRICA—Continued

Variety number	Seed and plant introduction number	Variety name or seed characteristics	Source (seedsman or locality)	Years tested	Anthracnose			Bacterial blight	Bacterial wilt		Mosaic
					Greenhouse inoculations		Field inoculations	Field inoculations	Greenhouse inoculations	Field inoculations	Field data
					Biologic forms			Extent of infection	Percentage of seedlings with one more leaves permanently wilted	Percentage of plants killed from seedling inoculations and extent of infection on older plants	Extent of natural infection
					Alpha, extent of infection	*Beta* and *gamma* combined, extent of infection	*Alpha*, *beta*, *gamma*, and I to VIII, inclusive, combined, extent of infection				
		Pole varieties (except Nos. 574 and 613)—Continued									
643	50893	Large, white pea beans (very late).	Nyanza	1921–1923	None	Very severe	Moderate	Moderate	100	None	Slight.
644	50894	Small, white navy beans	do	1921–1923	Very severe	None	do	Severe	100	60	Severe.
645	50895	Long, white beans	Kigoma	1921	No data	No data	None	Moderate	No data.	No data.	Slight.
646	50896	Large, black pea beans	Nyanza	1921–1923	Severe	Very severe	Moderate	Severe	100	None	Moderate.
647	50897	Long, black beans	do	1921–1922	No data	No data	None	do	No data.	No data.	Slight.
648	50898	Long, flat, black beans, slightly longer than above.	do	1921–1923	Moderate	Moderate	Slight	do	67	None	Moderate.
649	50899	Very small, sooty-black beans (similar to No. 535 from Kenya Colony).	do	1921–1923	Very severe	None	Very severe	do	100	do	Very severe.
650	50900	(A) *Light-brown beans with dark stripes.*	do	1923	None	Slight	Slight [a]	Moderate	50	do	Do.
651		(B) Long, flat, bluish-black beans.	do	1921–1923	No data	Very severe	Moderate	Severe	56	do	None.
652	50965	Long, narrow, mottled purplish beans with greenish stripes.	do	1921	do	No data	None	do	No data.	No data.	Do.

VENEZUELA

(Seed presented by H. Pittier, Caracas)

653	46363	Caraota blanca	Caracas	1920	No data	No data	None	Severe	No data.	No data	Very severe.
654	46369	Caraotas indiecita pequeña.	do	1920	do	do	do	do	do	do	Severe.
655	46366	Caraota negra	do	1920	do	do	do	Slight	do	do	Moderate.
656	46180	Caraotas bayas	Maracaibo	1920	do	do	do	Severe	do	do	Do.
657	46179	Caraotas negras	do	1920	do	do	do	Moderate	do	do	None.
658	46181	Caraotas pintadas	do	1920	do	do	do	do	do	do	Severe.
659	46368	Guacamaya	Caracas	1920	do	do	do	Slight	do	do	Slight.
660	46370	*Guaracaro colorado*	do	1920	do	do	do	None [b]	do	do	None.
661	46365	*Guaracaro redondo pintado*	do	1920	do	do	do	do. [b]	do	do	Moderate.
662	46364	Huevo de paloma	do	1920	do	do	do	Moderate	do	do	Very severe.
663	46362	Poncha rosado	do	1920	do	do	do	do	do	do	Moderate.
664	46367	Poncha rosada jaspeada	do	1920	do	do	do	do	do	do	Slight.

[a] Resistant to anthracnose.

[b] Resistant to bacterial blight

TABLE III.—*Detailed results of greenhouse inoculations with a combined spore suspension of all known biologic forms of Colletotrichum lindemuthianum on some of the more resistant varieties and on certain others concerning which the information in Table II is incomplete or lacking*

Variety number	Name or seed characteristics	Source	Number of plants showing the extent of infection indicated						Remarks
			Very severe	Severe	Moderate	Slight	Very slight	None	
11	Dwarf Golden Carmen	Roger Bros.	------	------	------	------	7	------	Apparently resistant.
115	Large, light-brown beans with greenish-brown stripes.	Belgian Congo.	------	------	------	------	------	20	Immune.
255	Coco marbre nain	France	10	20	------	------	------	------	Very susceptible.
273	Flageolet Mervielle de France.	do	------	1	11	------	------	------	Moderately susceptible.
286	Jaune de la Chine	do	------	------	------	7	------	------	Apparently resistant.
289	L'Inépuisable	do	------	10	------	------	------	------	Susceptible.
293	Nain blanc quarantain	do	1	21	5	------	------	------	Do.
301	Nain Parisien	do	------	------	------	15	5	------	Resistant.
325	Coco bicolore du Pape	do	------	22	------	------	------	------	Susceptible.
327	Coco blanc	do	1	5	------	------	------	------	Do.
336	Mangetout de la Vallée	do	5	9	7	------	------	------	Do.
339	Mangetout du Maine	do	------	8	4	------	------	------	Do.
344	Princess	do	------	4	15	------	------	------	Moderately susceptible.
375	Phänomen	Germany	2	10	------	------	------	------	Susceptible.
376	Präsident	do	16	------	------	------	------	------	Very susceptible.
377	Schmalzgrosse	do	------	9	1	------	------	------	Susceptible.
386	Negro pequeño mata (Strain A).	Guatemala	------	------	7	2	------	18	Very resistant.
404	Blanco de vara	do	------	------	1	------	14	4	Do.
408	Colorado	do	------	------	3	1	4	20	Do.
413	De sarco	do	------	1	------	------	------	24	Immune.
429	Negro pequeño	do	------	3	21	------	------	------	Moderately susceptible.
433	Pilique colorado	do	------	------	2	6	------	23	Very resistant.
442	Varitas	do	------	------	1	12	11	------	Resistant.
451	Small red kidney beans	do	------	2	8	------	------	23	Very resistant.
455	White pea beans	do	------	------	------	------	------	23	Immune.
464	Best of all speckled seeded, stringy.	Holland	4	------	15	6	------	------	Moderately susceptible.
465	Best of all speckled seeded, stringless.	do	6	13	8	------	------	------	Susceptible.
466	Best of all white seeded, stringy.	do	------	------	------	8	5	------	Apparently resistant.
467	Best of all white seeded, stringless.	do	25	9	------	------	------	------	Very susceptible.
468	Dark dun or liver color	do	------	23	8	------	------	------	Susceptible.
469	Delicata stringless	do	------	------	6	------	2	3	Moderately susceptible.
471	Early white farming	do	------	9	16	------	5	------	Do.
476	Perfect dwarf white stringless.	do	------	------	13	------	------	1	Do.
477	Princess white, stringy	do	------	11	5	------	------	------	Susceptible.
479	Transvalian, stringless	do	------	------	------	38	------	4	Apparently resistant.
496	Quarantino bianco	Italy	------	------	5	14	------	7	Somewhat resistant.
525	Osaya Dais Ingen	Japan	------	------	3	4	------	------	Apparently somewhat resistant.
528	Suzunari Ingen	do	------	29	------	------	------	------	Susceptible.
548	Short, drab beans with dark ring around the hilum.	Uganda	10	------	------	------	------	------	Very susceptible.
551	Short, light-green beans with brown ring around the hilum.	do	------	------	------	------	------	14	Immune.
552	Short, greenish-tan beans with brown ring.		------	------	------	------	------	15	Do.
594	Short, plump Sudan-brown beans.	Urundi	------	------	------	------	------	28	Do.
597	Purple-chocolate colored marrow beans.	do	------	------	------	------	------	21	Do.

TABLE III.—*Detailed results of greenhouse inoculations with a combined spore suspension of all known biologic forms of Colletotrichum lindemuthianum on some of the more resistant varieties and on certain others concerning which the information in Table II is incomplete or lacking*—Continued

Variety number	Name or seed characteristics	Source	Number of plants showing the extent of infection indicated						Remarks
			Very severe	Severe	Moderate	Slight	Very slight	None	
603	Finely stippled lavender kidney beans with olive-green stripes.	Urundi					3	23	Immune except for small percentage of slightly susceptible sports.
607	Long, finely stippled blue-tan beans with black stripes.	do						7	Apparently very resistant.
619	Small, lavender mottled beans with dark ring around hilum.	do						25	Immune.
625	Long, reddish-lavender mottled beans with dark ring around hilum.	do	18	9					Very susceptible.
631	Small, flat, yellowish-tan mottled beans.	do			3			13	Immune except for small percentage of susceptible sports.
633	Short, thick purple-chocolate colored beans.	do						57	Immune.
635	Small, flat pink beans	do	6	4					Very susceptible.
639	Small, flat dark-tan beans.	do	2	4	5	8		18	Resistant except for a fair percentage of susceptible sports.

The reaction of a number of the varieties listed in Table III shows, as expected, that the conditions for infection in the field plot of 1923 were not uniformly favorable enough to reveal the differences in susceptibility brought out by this severe greenhouse test. The same phenomenon has been repeatedly noted by Barrus (*1*) and others in comparisons of greenhouse and field inoculations with anthracnose. It seems to prove that field conditions are rarely as severe as the artificial greenhouse combination, and that varieties which are seldom more than slightly infected under commercial cultivation may develop the disease to a moderate or even a severe extent in the greenhouse.

The 12 varieties and strains used as controls in this experiment were, with one exception, all severely or very severely infected; the exception (Well's Red Kidney) showed infection only to a moderate extent.

In this test 12 varieties proved to be practically immune to all the 11 cultures or biologic forms of *Colletotrichum lindemuthianum*, e. g., Nos. 115, 413, 455, 551, 552, 594, 597, 603, 607, 619, 631, and 633. However, comparisons of their reaction in earlier greenhouse inoculations and field tests (Table II, columns 6 to 8) show that all but No. 633 are listed in one column or another as very slightly infected. This apparently contradictory evidence is probably due as much to variation in judgment of the observer as to real variation in the extent of infection. While the definitions of immunity (i. e., no infection) and "very slight" infection, in Table I, would seem to

partially eliminate this possibility, yet in actual practice enough intergradation has been observed to make the personal equation an important factor. This, coupled with the fact that the information was obtained in different years and by different people, leads the authors to attach very little significance to expressed differences between "very slight" and "none" as used for this disease.

Coordinating the evidence in both Tables II and III, and considering only those varieties on which there is fairly adequate information with respect to their behavior toward anthracnose and bacterial blight, the resistant material isolated in this study may be classified as follows:

1. Varieties apparently resistant to both anthracnose and bacterial blight:
   - 594, S. P. I. 50850, small brown beans, pole type, from Urundi.
   - 451, S. P. I. 53808, small red kidney, pole type, from Guatemala.
   - 115, S. P. I. 48472–C, large, light-brown striped beans, pole type, from Belgian Congo.
   - 597, S. P. I. 50853, purple-chocolate colored marrow beans, pole type, from Urundi.
   - 118,[a] S. P. I. 48472–F, bluish-striped kidney, pole type, from Belgian Congo.
2. Varieties apparently resistant to anthracnose:
   Infection, none—
   - 551, S. P. I. 52192, dwarf type, from Uganda.
   - 552, S. P. I. 52193, dwarf type, from Uganda.
   - 603, S. P. I. 50859–B, pole type, from Urundi.
   - 619, S. P. I. 50873–A, pole type, from Urundi.
   - 633, S. P. I. 50885, pole type, from Urundi.
   - 638,[a] S. P. I. 50888–A, pole type, from Urundi.

   Infection very slight—
   - 117,[a] S. P. I. 48472–E, pole type, from Belgian Congo.
   - 404, S. P. I. 53875, Blanco de vara, pole type, from Guatemala.
   - 413, S. P. I. 53792, De Sarco, pole type, from Guatemala.
   - 455, S. P. I. 53817, white pea beans, pole type, from Guatemala.
   - 607, S. P. I. 50861–C, pole type, from Urundi.
   - 627,[b] S. P. I. 50879–B, pole type, from Urundi.

   Infection slight—
   - 245,[b] Beurre blanc nain, dwarf type, from France.
   - 269,[b] Flageolet blanc extra, dwarf type, from France.
   - 286, Jaune de la Chine, dwarf type, from France.
   - 299,[b] Nain Mangetout extra-hâtif, dwarf type, from France.
   - 301, Nain Parisien, dwarf type, from France.
   - 386, S. P. I. 53784–A, Negro pequeño mata, dwarf type, from Guatemala.
   - 408, 53781, Colorado, pole type, from Guatemala.
   - 424,[a] 53775, Negro de vara, pole type, from Guatemala.
   - 466, Best of All, white, stringy, dwarf type, from Holland.
   - 479, Transvalian stringless, dwarf type, from Holland.
   - 525, Osaya Dais Ingen, pole type, from Japan.
   - 617,[b] 50872–A, pole type, from Urundi.
   - 618,[b] 50872–B, pole type, from Urundi.
   - 631, 50883, pole type, from Urundi.
   - 650,[b] 50900–A, pole type, from Urundi.
3. Varieties apparently resistant to bacterial blight:
   - 19, Hodson Wax.
   - 20, Keeney Rustless.
   - 45, French's Horticultural.
   - 72, Robust (Nelson selection).
   - 80, Refugee (Roger selection).
   - 85, White Imperial.
   - 89, Baldwin Wonder Wax, pole.

[a] Classified as resistant on basis of negative reaction to the *alpha*, *beta*, and *gamma* biologic forms in greenhouse tests and to all of the 11 forms in the field.
[b] Loc. cit.

3. Varieties apparently resistant to bacterial blight—Continued.
   101, London Horticultural, pole.
   107, Worcester Mammoth, pole.
   283, Incomparable, dwarf type, from France.
   325, Coco bicolore du Pape, pole type, from France.
   351, Zébré gris, pole type, from France.
   395, S. P. I. 56584–A, Alubia, white kidney, dwarf type, from Guatemala.
   454, S. P. I. 56582, Light tannish-pink beans, pole type, from Guatemala.
   494, Meraviglia di Lione, dwarf type, from Italy.
   499, Varesotto, dwarf type, from Italy.
   528, Suzunari Ingen, pole type, from Japan.
   541, S. P. I. 51079, pole type, from Russia.
   544, S. P. I. 51082, pole type, from Russia.
   545, S. P. I. 51083, pole type, from Russia.
   549, S. P. I. 52191, dwarf type, from Uganda.
   556, S. P. I. 52198, dwarf type, from Uganda.
   565, S. P. I. 52201, pole type, from Uganda.
   577, S. P. I. 50259, pole type, from Urundi.
   578, S. P. I. 50260, pole type, from Urundi.
   589, S. P. I. 50846, pole type, from Urundi.
   615, S. P. I. 50870, pole type, from Urundi.
   621, S. P. I. 50875, pole type, from Urundi.
   626, S. P. I. 50879–A, pole type, from Urundi.
   635, S. P. I. 50886–B, pole type, from Urundi.
   636, S. P. I. 50886–C, pole type, from Urundi
   660, S. P. I. 46370, from Venezuela.
   661, S. P. I. 46365, from Venezuela.

From the above lists it is seen that, out of a total of 663 varieties and strains tested, 65 are considered more or less resistant to anthracnose or bacterial blight, of which 5 are classified in Group 1, 27 in group 2, and 33 in group 3. Several of the blight-resistant varieties in group 3 which appeared resistant also to anthracnose in the field tests doubtless belong in group 1, but their apparent resistance has not been confirmed by greenhouse inoculation. However, their field behavior confirms the results of Burkholder (*3*) and others.

Although a number of the varieties, particularly the first six in list 2, are practically immune to anthracnose, no such striking behavior toward bacterial blight was observed. No variety came through the test-plot epidemics of both 1921 and 1923 with less than "slight" blight infection. The degrees of infection less than "slight," defined in Table I, occurred, therefore, mainly on other species of the genus. As Burkholder (*3*) has pointed out, resistance to blight is manifested in other ways than merely by reduction in number or size of the lesions. The incubation period is noticeably longer and the lesions enlarge more slowly in case of the resistant variety, enabling it to mature a good crop in spite of the disease.

ADAPTABILITY AND DESCRIPTION OF ANTHRACNOSE AND BLIGHT RESISTANT TYPES

The adaptability and commercial value of the few standard American and European varieties, listed in groups 2 and 3, are fairly well known and as shown presently, could probably with advantage supplant certain very susceptible varieties of the same type now being grown in this country. Little is known of the horticultural value of the Central American and East African resistant beans. They are now being increased, selected for uniformity, and studied from the

standpoint of commercial utilization and suitability for hybridizing with certain susceptible American varieties. Although most of them have appeared quite uniform in their resistance, in a few cases much variability in plant characters has been noted. However, the foreign introductions which have thus far shown the least variability in type and which seem the most promising for hybridization are briefly described at this time.

The varieties in group 1 are either very tall pole types or bush beans with the pea-bean habit of growth. The color and shape of seed and extreme lateness make them unsuitable for direct use at least in the northern field-bean sections, and their tough, fibrous, stringy, small pods preclude their use anywhere as snap beans. They have all come fairly true to type and offer perhaps the most promising possibilities for hybridization work.

Of particular interest in group 2 are the S. P. I. Nos. 52192 and 52193 (variety Nos. 551 and 552) which are apparently identical in plant characters and reaction to disease. Both have a dwarf, indeterminate habit, with short, thick, green, tough, pods containing three or four slate green, marrow type seeds. They are much earlier than the varieties in group 1, but are less productive. Both varieties might be used advantageously in crosses with many of our high quality but susceptible garden types, and with the kidney and marrow field beans, to introduce resistance to all the biologic forms of the anthracnose fungus.

The variety *Negro pequeño mata* (No. 386, S. P. I. 53784–A) is perhaps the most promising for introducing anthracnose resistance into white pea beans such as Early Wonder and Michigan Robust. It develops large, spreading, indeterminate plants with dark-green foliage, very late and productive; pods pea-bean type in color and size; seeds black, pea-bean shape and size but somewhat flattened.

The other South American and East African varieties in group 2 are apparently so far removed in horticultural characters from our American types that one would use them in hybridization only as a last resort.

The anthracnose-resistant French varieties in group 2 seem to have not only immediate commercial possibilities, but also offer promising material for crossing with such anthracnose-susceptible American types as Burpee's Stringless Green Pod, Giant Stringless Green Pod, Bountiful, Full Measure, Rogers Improved Green Pod Refugee, Refugee Wax, Sure Crop Wax, Pencil Pod Wax, Burpee Kidney Wax, Kentucky Wonder Pole, etc. Descriptions of these French varieties follow.

No. 245. *Beurre blanc nain*, described by Denaiffe (*4, p. 180*) and by Robinson (*10, p. 82*) as grown at Lansing, Mich., is of dwarf, indeterminate growth, about 12 inches high; foliage light green, medium size; flowers white; snap pods stringy, parchmented; of transparent, greenish-yellow color, flat, slightly curved, 5 or 6 seeds per pod, 4 to 5 inches long, ½ to ⅝ inch wide; season early; dry seed white, medium size, oval in cross section, rounded ends, large pea-bean type. The dried seed is said to be excellent for table use. This variety, because of its resemblance in many ways to a pea-bean type, might be used in crosses with Michigan Robust to secure an anthracnose-resistant pea bean. It would also be a valuable type to use in crosses with American sorts where a white seeded garden or canning variety is desired, but the pods are too pale a yellow to make it useful in hybridizing with a susceptible green podded type to secure a resistant wax-podded segregate.

No. 269. *Flageolet blanc extra*, described by Robinson (*10, p. 56*) and Denaiffe (*4, pp. 142, 143*), is said by the former to be the best known and most esteemed

of the tough-podded kidney beans in France. As grown at Lansing, Mich., the plants are of dwarf, indeterminate growth, 12 inches high; foliage small, medium green; flowers white; pods green, oval in cross section, curved, 4½ to 5 inches long, ⅜ inch wide, stringy, parchmented, 4 or 5 seeds per pod; dry seeds medium size, flat, $\frac{11}{32}$ inch long, $\frac{7}{32}$ inch wide, and $\frac{1}{32}$ inch thick, kidney-shaped, excellent as green shell beans. This variety may be used in hybridization the same as Beurre blanc nain, while the longer, narrower pods make it more desirable for crossing with garden types.

No. 299. *Nain mangetout extra-hâtif*, described by Denaiffe (*4, pp. 160, 161*). As grown at Lansing, Mich., plants are very dwarf, 6 to 8 inches high, determinate, very early; foliage light green; pods green, round, slightly curved, stringy, parchmented, 3 to 3½ inches long, ⅜ inch wide, 4 or 5 seeds per pod; dry seed white with light yellow ring around hilum, ½ inch long by ¼ inch wide by ¼ inch thick, round in cross section, rounded ends. This variety seems to have no direct horticultural uses in this country, but appears of value to use in crosses where a very early, resistant bean is desired.

No. 286. *Jaune de la Chine*, described by Robinson (*10, p. 88*) and by Denaiffe (*4, p. 295*). Plants dwarf, 16 inches high, much branched, determinate; foliage medium-sized, light green; pods green, 5 inches long, 5/16 inch wide, round, slightly curved, stringy, parchmented when old, 5 or 6 seeds per pod; productive, mid-season; seeds yellow, bluish ring around hilum, ⅝ inch long, ovoid or subspherical in shape. Because of its anthracnose resistance and usefulness as a snap and green shell bean, this variety may be worthy of trial to supplant susceptible green shell types, such as Low's Champion. According to Jarvis (*6*) Jaune de la Chine was formerly much cultivated in this country under the name Yellow Cranberry, but has now almost gone out of use.

No. 301. *Nain Parisien*, described by Robinson (*10, p. 59*) and by Denaiffe (*4, p. 232*), has a dwarf plant of vigorous growth, determinate, dark green leaves, lilac-colored flowers; pods straight, cylindrical, 6 to 6½ inches long, dark green with purple streaks that disappear on cooking, parchmented, not stringy; very productive, mid season; seeds large, flat, kidney-shaped, streaked dark purple on chamois. The purple streaking on the pods make this variety unsuitable from a market-garden standpoint to supplant susceptible varieties, such as Black Valentine, but the general horticultural characters of Nain Parisien make it more useful for hybridizing than the late coarse-vined South American sorts in group 2.

RESISTANCE TO BACTERIAL WILT

The information on bacterial wilt, as explained earlier, is insufficient as a basis for judging relative susceptibility. However, 15 of those varieties inoculated by the "cotyledon method," which appeared least affected and are marked in Table II with the letter *c*, may on further testing prove to be somewhat resistant to this disease. The results of the needle-prick inoculations on older plants are even less valuable for comparative purposes. Yield of inoculated and control plants would doubtless have given a better basis for comparison than the more or less artificial classification of infection used in these preliminary experiments. Replication of tests and careful comparisons with controls would be necessary, however, to offset possible complicating factors, as natural spread of wilt on controls, infection by other diseases, and differences in time of maturity of the varieties.

The extremely severe type of wilt produced by inoculations in the cotyledon stage is comparable, in the writers' observations, to naturally occurring early season field cases resulting from seed infection, while the symptoms produced by later inoculations are similar to the more prevalent but individually less severe type resulting, apparently, from secondary spread in the field. Occasionally, however, general and severe wilting follows these late infections, as shown by the case illustrated in Plate 3, A.

TESTS ON RELATED SPECIES OF PHASEOLUS AND ON OTHER BEAN GENERA

Lima bean (*Phaseolus lunatus* L.).—Along with the varieties of the common bean there were included, during one or more of the four years of field testing, 21 of the commonly listed American dwarf and pole varieties of lima beans and 62 foreign varieties, from 12 different countries. The short growing season and other unfavorable conditions for this type of bean at the latitude of Lansing, Mich., prevented the obtaining of reliable comparative data. In general, most of the varieties appeared to be more or less susceptible to blight and usually showed a slight to moderate amount of anthracnose and mosaic. More variation was noted with respect to bacterial wilt, the extent of infection ranging from none in the case of Henderson and Wood Prolific, to severe in Burpee Bush from both field and greenhouse inoculations.

Runner beans (*Phaseolus multiflorus* Willd.).—Most of the 57 varieties and strains of runner beans included in the field tests developed both anthracnose and bacterial blight to a slight or moderate extent and frequently showed traces of mosaic. No signs from any of the inoculations with the bacterial wilt organism.

Tepary beans (*Phaseolus acutifolius* Gray.).—A selection of both white and colored seeded varieties tested in field plots showed rarely more than a trace of bacterial blight and a moderate to severe amount of anthracnose. No wilt or mosaic was observed.

Adzuki bean (*Phaseolus angularis* (Willd.) Wright).—Infection slight with bacterial blight and mosaic, and none with anthracnose in field tests; severely infected with bacterial wilt in greenhouse tests.

Mung bean (*Phaseolus aureus* Roxb.).—Traces of bacterial blight in the field; immune to anthracnose but susceptible to wilt in both greenhouse and field tests.

Rice bean (*Phaseolus calcaratus* Roxb.).—No infection from any of the diseases on the two varieties, S. P. I. 46427 and 56072, tested in both field and greenhouse; not inoculated with wilt organism.

Urd bean (*Phaseolus mungo* L.).—No infection from greenhouse inoculations with the *alpha*, *beta*, and *gamma* forms of *Colletotrichum lindemuthianum*. Slightly susceptible to bacterial blight, and moderately susceptible to bacterial wilt in greenhouse tests.

Cowpea (*Vigna sinensis* (L.) Endl.).—Slight to moderate infection in field tests with anthracnose and bacterial blight on majority of 15 varieties from different sources; greenhouse wilt inoculations negative.

Asparagus bean (*Dolichos sesquipedalis*, L.).—Anthracnose occasionally very slight on leaves in greenhouse tests; no positive evidence of bacterial blight and wilt; mosaic usually severe.

Hyacinth bean (*Dolichos lablab* L.).—Dolique Mongette from France, slight mosaic and an undetermined leaf spot resembling bacterial blight.

Jack bean (*Canavalia ensiformis* (L.) DC.).—No signs of any of the four diseases in field tests.

SUMMARY

This paper presents a summary of four years' bean varietal testing for resistance to anthracnose and bacterial blight. The results of preliminary greenhouse and field inoculations with bacterial wilt and notes on the natural occurrence of mosaic, obtained incidental to this study, are also included.

A total of 663 varieties and strains of beans have been tested, of which 170 are American and 493 foreign, the latter being obtained from 23 countries.

The data on relative susceptibility to bacterial blight are limited to field-plot inoculations which, in 1923, were replicated in three different localities. A large proportion of the foreign varieties were also subjected to carefully controlled greenhouse tests with the various biologic forms of the anthracnose fungus. Since some of the varieties were tested in the field only during years unfavorable for epidemic development of one or another of the diseases, the results on these are necessarily of a preliminary nature.

Considering only those varieties on which there is fairly conclusive evidence, a total of 65 appear to possess decided resistance to anthracnose or bacterial blight, of which 5 are resistant to both diseases, 27 to anthracnose alone, and 33 to bacterial blight alone. A few of the blight-resistant types may, however, prove to be also resistant to anthracnose if their apparent resistance in field tests is confirmed by greenhouse inoculations.

Six of the 27 anthracnose-resistant varieties are practically immune to all known biologic forms of the fungus, as shown both by greenhouse and field inoculations. The remainder were affected only to a slight or very slight extent.

No very high degree of resistance to bacterial blight was observed in any variety of *Phaseolus vulgaris* tested. Although additional comparative evidence is required, a number of the foreign varieties, however, appear to be somewhat more resistant than any of our American types.

Very little is thus far known regarding the adaptability of the foreign varieties used in this study for direct commercial cultivation in the United States. Since some of the most resistant are late pole types of tropical or semitropical origin, it is inferred that these, at least, will be mainly valuable for hybridization with our susceptible American types.

Tests conducted on a large collection of varieties of related species and genera of beans are briefly summarized.

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EFFECT OF DEHYDRATION UPON THE BACTERIAL FLORA OF EGGS[1]

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INTRODUCTION

The commercial dehydration of broken-out eggs has been developed to minimize the losses incident to shipment and storage where long distances and long periods of time are involved. The reduction in volume and weight alone is significant, but the reduction in the demands on cold-storage facilities and the need for expensive and elaborate packing methods is still more important. Dehydration has made possible the development of large egg-handling establishments in China, which at present supply most of the dried egg used by the baking industry in the United States.

Sound fresh eggs subjected to one of the controlled drying processes make a very desirable dried product. The practices involved in the breaking and mixing of large quantities of commercial eggs, however, introduce so many opportunities for spoilage and contamination that a bacterial examination of the number and character of the bacteria, and a study of the opportunities for the growth of the microorganisms, seem desirable. Bacterial findings must be correlated with the odor, taste, or other evidence of soundness or spoilage in the manufactured product, and with the same properties in the raw materials.

Sources of contamination during dehydration are the hands of the operator, the apparatus, dirt from the air or from the surface of the shell, and the fragments of shell unavoidably left in the product.[3] Perhaps the principal source is the occasional single egg which contains large numbers of bacteria but has not developed physical evidence of spoilage by odor or taste. Such eggs have been found and reported in the investigations of Jenkins and Hendrickson.[4] Also, many eggs which have been damaged in handling become contaminated with microorganisms in considerable numbers before evidence of decomposition is noticeable. Therefore, a mixed product selected as sound by physical examination may at times contain a large number of bacteria per cubic centimeter. It seems fair to assume that a great many bacteria may be introduced without there having been negligence or gross carelessness in the preparation of the original mix.

With such initial bacterial contamination, enormous numbers of bacteria will develop in a comparatively short time, if the mix is

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[2] This investigation was a part of a bacteriological and chemical study of dried eggs conducted in cooperation with H. W. Redfield, G. C. Swan, and H. I. Macomber. Acknowledgment is due Charles Thom for many suggestions.

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held at a temperature other than that of effective refrigeration. An efficient egg-drying process, therefore, must provide for the immediate chilling or freezing of the broken-out product or for its prompt dehydration.

In the course of dehydration the products are subjected to contact with heated air, which removes, partially at least, the volatile constituents. This removes or changes the odors characteristic of the fresh sound product and reduces or destroys the odors in low-grade eggs incident to spoilage, which would readily be recognized in the liquid egg. The odor of commercially dried eggs, therefore, may be expected to differ sufficiently from that of the fresh product to require careful examination by experienced analysts.

The odor, appearance, and taste of dehydrated egg differ so markedly from those of fresh liquid egg that extensive experience is necessary to coordinate the two kinds of egg.

In planning a bacteriological examination of dehydrated eggs, all of these factors must be taken into consideration. Theoretically, the number of living bacteria in the finished product depends on the number and kind of bacteria in the liquid product, the temperature to which the product is subjected, and the length of time at which that temperature is maintained. Furthermore, in view of the fact that most of the dried eggs used in this country are imported, the effect of the time and conditions of storage upon the bacterial count becomes important, if that count is to be used as an index of quality.

It is believed that the air is an unimportant source of contamination under proper conditions in the factory. This is certainly true of the processes studied in this investigation. Likewise, the amount of contamination from utensils is insignificant, if they are clean and dry. If the utensils are wet or improperly cleaned, however, the product will have more organisms in the portions in contact with such contamination. From the bacteriological standpoint, the moisture content of the dried product, and the evenness of the drying, are the factors which must be closely watched if a desirable and uniform product is to be obtained.

Two dehydration processes for eggs—the spray and vacuum-drum—were studied by the Bureau of Chemistry, United States Department of Agriculture, in the summers of 1922 and 1923. In both of these processes liquid egg was dried to a powder of low moisture content in a short time. Bacterial action during this short drying period was considered negligible. The content of living organisms in the egg powder represents the effect of the temperature, time of exposure at that temperature, and degree of the concentration of the product upon whatever organisms were initially present.

SPRAY PROCESS

GENERAL PROCEDURE

In the spray process, the first method studied, the egg was exposed to a temperature of about 75° C. for 18 to 25 minutes. Briefly, this process consisted in forcing liquid egg, under great pressure, through a fine spray apparatus, into a collecting chamber in which dehydration was accomplished by exposure to a large volume of heated air. The egg particles remained exposed on the floor of the heated chamber for the period of the "run," approximately 20 minutes.

GRADES OF EGGS USED

Two grades of eggs—good (commercial firsts) and inedible—were used. The inedible grade contained white rots, spots, and other types. In view of the fact that the eggs were broken under supervision at the breaking table, it was not thought necessary to candle the good eggs. The inedible eggs were candled and separated into the various classes. Each grade was broken out at the breaking table under the writer's supervision. The liquid egg was thoroughly mixed, and was dried immediately. From the drier, the powder was placed on trays and cooled, and then placed in friction-top cans which were finally sealed with paraffin.

EXPERIMENTS NOS. 1, 2, AND 3

WHOLE EGG.—The eggs used (30-dozen cases for each experiment) were purchased on the open market as first grade eggs. In order to have as uniform a product as possible, the following restrictions were made: All eggs which had a doubtful appearance after being broken out were discarded. If the eggs were "off" in color or odor, they were not used. The few green whites found were discarded, as were eggs in which the yolks were reddened, but not showing development of the embryo. Eggs in any way questionable were discarded.

EXPERIMENTS NOS. 4, 5, 6, AND 7

YOLK.—The quality of the eggs and the grading at the breaking table were the same as those in Experiments Nos. 1, 2, and 3. The yolks were separated carefully from the whites. The yolks from six cases were used in each experiment.

EXPERIMENTS NOS. 8 AND 9

YOLK.—In Experiment No. 8 the yolks of sound eggs, after being mixed, were allowed to stand at the temperature of the breaking room (about 25° C.), for approximately 15 hours before drying, and for approximately 24 hours in Experiment No. 9. Six cases were used in each experiment.

EXPERIMENTS NOS. 10 AND 11

HEATED WHOLE EGG.—Commercial firsts were placed in the sun. The course of their deterioration was followed by candling. The whites were very thin when broken out at the table. Black rots, white rots, and spot eggs were not used. Three cases were used in each experiment.

EXPERIMENT NO. 12

YOLK.—The treatment, grading, and quality of the eggs were the same as those in Experiments Nos. 10 and 11. The yolk membranes were firm, so that no difficulty was encountered in separating. Six cases were used.

EXPERIMENT NO. 13

WHOLE EGG.—The eggs in this and the following experiments were candled. This experiment was made on 28 dozen doubtful eggs and 48 dozen spots. Tne eggs which were graded as doubtful by the candler had weak yolks and watery whites, and there were some white rots.[5] All eggs were used except black rots.

[5] JENKINS, M. K., and HENDRICKSON, N. Op. cit., found that white rots were passed occasionally by candlers.

EXPERIMENT NO. 14

WHOLE EGG.—The egg used consisted of six dozen blood rings, 55 dozen addled eggs, and 15 dozen spots. In the blood rings there were no definitely marked embryos. The addled eggs contained white rots and green whites. All black rots were discarded.

EXPERIMENT NO. 15

WHOLE EGG.—In this experiment 54 dozen addled eggs and 24 dozen mixed rots, but no black rots, were used.

BACTERIOLOGICAL EXAMINATION

Samples of the liquid product were taken for bacteriological examination just before it was taken to the drier. They were collected in sterile glass jars, and placed in the sharp freezer and kept frozen until examined. Samples of the dried product were taken after it was cool, and again just before it was placed in the tin containers.

The odors of the liquid and dried egg were compared carefully. There was no difficulty in determining the quality of the liquid egg, but some volatile material was lost during the drying process, which made grading more difficult in the dried products. The dried product prepared from good eggs could be differentiated very easily from that prepared from rotten eggs. The number of bacteria in the liquid and dried egg is shown in Table I.

TABLE I.—*Number of bacteria in liquid and dried egg (spray process)*

Sample No.[a]	Type	Quality	Total bacteria on nutrient agar at—		Colon group	BCP lactose agar[b] 37° C. for 2 days	
			37° C. for 2 days	20° C. for 4 days		Total	Acid
1L	Whole	Good	75,000	65,000	100	147,000	8
1D	do	do	450	400	0	500	0
2L	do	do	225,000	225,000	0	380,000	0
2D	do	do	1,700	3,300	0	2,200	900
3L	do	do	7,500	8,000	100	23,000	4,000
3D	do	do	350	350	0	900	600
4L	Yolk	do	530,000	550,000	100,000	630,000	300,000
4D	do	do	550	550	0	700	40
5L	do	do	78,000	80,000	1,000	97,000	1,000
5D	do	do	320	550	0	800	50
6L	do	do	21,000	5,500	0	24,000	1,000
6D	do	do	115	500	0	100	40
7L	do	do	190,000	220,000	100	330,000	0
7D	do	do	1,460	170	10	1,400	0
8L	do	Good, held[c]	350,000	370,000	10,000	600,000	0
8D	do	do	370	285	10	380	60
9L	do	do[d]	650,000	475,000	100,000	3,000,000	1,600,000
9D	do	do	9,100	5,150	10	8,400	0
10L	Whole	Heated	1,700,000	820,000	100,000	2,700,000	300,000
10D	do	do	4,900	1,220	0	6,400	300
11L	do	do	1,600,000	1,050,000	1,000,000	4,400,000	300,000
11D	do	do	1,350	330	10	1,070	0
12L	Yolk	do	500,000	635,000	100,000	1,160,000	500,000
12D	do	do	2,950	650	10	3,500	0
13L	Whole	Doubtful, spots	23,500,000	17,500,000	1,000,000	28,000,000	6,000,000
13D	do	do	58,000	320,000	10	350,000	350,000
14L	do	Blood rings, addled spots.	106,000,000	94,000,000	10,000,000	109,000,000	160,000,000
15L	do	Addled, mixed rots	187,000,000	149,000,000	10,000,000	178,000,000	10,800,000
15D	do	do	410,000	740,000	0	680,000	120,000

[a] L designates the liquid product; D designates the dried product.
[b] Brom cresol purple lactose agar.
[c] Held 15 hours at 25° C.
[d] Held 24 hours at 25° C.

All counts were made on the gram basis of the liquid product. For the liquid egg, the sample was weighed in a glass-stoppered flask, on an analytical balance, to the nearest one-hundredth of a gram, and nine times that weight of physiological salt solution (considering that 1 c. c. is equal to 1 gm.) was added. This was called the 1 : 10 dilution. Sterile glass beads were added to help break up the egg. In the analyses of the dried product, salt solution was added to give approximately the same percentage of total solids as in the 1 : 10 dilution of the liquid product. This was taken as the 1:10 dilution of the dried product. By this procedure the counts of the dry product were comparable with those of the liquid product.

There was some difficulty in obtaining solutions of the dried product. Apparently the powder did not go completely into solution, but was broken up very finely to form a suspension, so that the product could be regarded as in solution only when no large undissolved particles were present.

The results in Table I show that there is a big reduction in the total number of viable bacteria, and in some cases a complete loss of the colon-aerogenes group, during the drying process.

In addition to the total bacteria counted, a large number of organisms were isolated from the spray-process samples. Some of these organisms of general types, as those of the colon group and a few of the aerobic spore-formers, were identified, but most of them could not be identified absolutely. Organisms of the colon type were predominant in the liquid product, and organisms of the aerogenes type were predominant in the dried products. This change in the types might be explained either by a difference in the heat resistance of the two types, or by a greater sensitiveness of the colon type to the change in pressure involved in the spray process. Further experiments have not been carried out to prove which of the two hypotheses is correct.

VACUUM-DRUM PROCESS

GENERAL PROCEDURE

Experiments in drying eggs by the vacuum-drum method were undertaken in the summer of 1923. Chemical and bacteriological analyses were made on the liquid and dried products, and the odor before and after drying was noted. The plan of the work was similar to that followed in the spray process.

The eggs were broken and dried as in the spray process, and mixed by hand with a perforated disk. Two cases were broken each day. The first case was dried approximately 2 hours after breaking. The second was held in an ice box, and dried approximately 5 hours after breaking. The temperature of the drum was usually about 90° C., but a few of the samples were dried at 88°, and a few at 93°. The exposure was 15 to 20 seconds.

GRADES OF EGGS USED

A few eggs of each grade were candled before the experiments were started. Inspection of the eggs at the breaking table, however, was taken as the best way of ascertaining the quality. Three grades were used—commercial firsts, heated, rots and spots. In general, the commercial firsts proved to be of very good quality. A few showed a little heat. The heated eggs were uniformly of

poorer quality than the first grade. Many of the eggs showed a thinning of the white, and some of the whites were slightly opaque. The rots and spots were classified at the breaking table. Grading was done at the breaking table. Table II gives the results of grading for the eggs used in all the experiments except Nos. 14 and 15. In Experiment No. 14 the numbers and types of eggs determined at the breaking table were 2 black rots, 28 white rots, 2 red rots, 1 moldy, 185 mixed rots, 20 sour, 26 blood rings, and 81 spots. Experiment No. 15 showed 11 red rots, 29 white rots, 187 mixed rots, 24 sour, 13 blood rings, and 88 spots.

One 30-dozen case of eggs was used in each experiment on whole eggs, and two cases in each experiment on whites and yolks.

BACTERIOLOGICAL EXAMINATION

The bacteriological samples were taken at the time of drying in the case of the liquid product and immediately after the drying in the case of the dried product. The method of analysis was the same as that in the experiment with the spray-process dried egg.

Results of the bacteriological examination are shown in Table II.

TABLE II.—*Number of bacteria in liquid and dried eggs (vacuum-drum process)*

Sample No.[a]	Type	Quality	Total bacteria on nutrient agar at—		Colon group	BCP lactose agar[b] 37° C. for 2 days	
			37° C. for 2 days	20° C. for 4 days		Total	Acid
1L	Whole	Good	54,000	137,000	10,000		
1D	do	do	45,000	67,000	10		
2L	White	do	2,600	2,850	1,000		
2D	do	do	40	60	0		
3L	do	do	166,000	189,000	10,000	111,000	53,000
3D	do	do	18,000	21,000	1,000	18,000	8,300
4L	Yolk	do	2,950	1,600	100		
4D	do	do	1,800	900	100		
5L	do	do	248,000	235,000	10,000	210,000	10,000
5D	do	do	22,000	30,000	0	19,000	61,000
6L	White	Good, held[c]	207,000,000	166,000,000	10,000		
6D	do	do	30,000	40,000	10		
7L	do	do[c]	4,400,000	4,900,000	1,000,000	5,400,000	100,000
7D	do	do	210,000	100,000	10	260,000	9,000
8L	Yolk	do[c]	600,000,000	600,000,000	100,000		
8D	do	do	1,800,000	900,000	1,000		
9L	do	do[d]	1,010,000,000	850,000,000	100,000,000	640,000,000	280,000,000
9D	do	do	22,400,000	35,000,000	10,000	16,000,000	12,000,000
10L	Whole	Heated	15,400,000	15,400,000	100,000	13,300,000	290,000
10D	do	do	760,000	6,400,000	10	750,000	670,000
11L	do	do	7,500,000	7,600,000	1,000,000	6,900,000	800,000
11D	do	do	120,000	180,000	0	200,000	100,000
12L	White	do	4,500,000	1,500,000	100,000	6,500,000	600,000
12D	do	do	1,010,000	1,620,000	10,000	740,000	40,000
13L	Yolk	do	10,000,000	17,000,000	1,000,000	4,200,000	3,100,000
13D	do	do	140,000	260,000	10,000	50,000	40,000
14L	Whole	Rots	164,000,000	170,000,000	10,000,000	100,000,000	33,000,000
14D	do	do	2,400,000	3,100,000	10,000	1,200,000	600,000
15L	do	do	108,000,000	150,000,000	10,000,000	104,000,000	25,600,000
15D	do	do	120,000	170,000	100	150,000	100,000

[a] L designates the liquid product; D designates the dried product.
[b] Brom cresol purple lactose agar.
[c] Held 24 hours before drying.
[d] Held 30 hours before drying.

The eggs dried by the vacuum process showed a smaller percentage decrease in the total count than the eggs dried by the spray process. This is explained by the fact that the vacuum process was less effective in killing the nonsporulating organisms.

RESULTS OF BACTERIOLOGICAL EXAMINATION

The heat applied to eggs by both processes killed a certain percentage of the organisms. This percentage increased as the total number increased, and varied with the type of organism. In most of the experiments the decrease in the numbers of the colon group was very large; the decrease in the numbers of the total lactose fermenters, as determined by the plate method, was decidedly smaller. A comparison of the counts on eggs dried by both methods showed that the vacuum-drum process is not as efficient as the spray process in killing bacteria.

The odor of the dried product was much less pronounced than that of the liquid product. Furthermore, the odor was stronger while the product was warm from the drier than after it had been cooled. Counts of the viable bacteria furnish little basis for estimating the quality of such products, especially where the details of their histories are not known.

EFFECT OF STORAGE

In order to determine the effect of temperature and time on the bacterial count, samples of the various grades of dried egg made by the spray process were stored for long periods.

The samples were placed in glass-stoppered salt-mouth bottles, sealed with paraffin, and held at 20° C., at room temperature (approximately 25°) and at 37°. By sealing with paraffin, the factor of variable humidity was eliminated. Total counts on plain agar incubated at 20° and 37°, total counts and the number of acid formers on brom cresol purple lactose agar, and counts of the colon group, were made at the beginning, at the end of 3 months, and at the end of 10 months. The results are shown in Tables III, IV, and V.

TABLE III.—*Effect of storage on bacterial counts of dehydrated eggs*

[Samples held in sealed bottles at approximately 25° C. and examined at the dates indicated] [a]

Sample No.	Type	Quality	Bacteria on plain agar held at—		Colon group	Bacteria on BCP agar [b] held at 20° C. for 4 days	
			20° C. for 4 days	37° C. for 2 days		Total	Acid
	June 20, 1922 (start):						
1	Whole	Good	350	350	0	900	600
2	Yolk	do	550	550	0	700	40
3	Whole	Heated	4,900	1,220	0	6,400	300
4	Yolk	do	2,950	650	10	3,500	0
5	Whole	Rotten	58,000	320,000	10	350,000	350,000
6	Do	do	410,000	740,000	0	680,000	120,000
	October 31, 1922:						
1	Whole	Good	230	145	0	200	0
2	Yolk	do	350	135	0	470	0
3	Whole	Heated	1,900	300	0	2,400	0
4	Yolk	do	2,800	95	0	1,900	0
5	Whole	Rotten	55,000	47,000	0	51,000	0
6	Do	do	145,000	101,000	0	87,000	0
	May 7, 1923 (37° C. for 2 days):						
1	Whole	Good	320	260	0	170	50
2	Yolk	do	335	170	0	290	40
3	Whole	Heated	930	210	0	210	30
4	Yolk	do	1,250	135	0	120	10
5	Whole	Rotten	36,000	26,000	0	29,000	27,000
6	Do	do	30,000	20,000	0	23,000	15,000

[a] The samples used in this experiment were dried by the spray process.
[b] Brown cresol purple lactose agar.

TABLE IV.—*Effect of storage on bacterial counts of dehydrated eggs*

[Samples held in sealed bottles at 20° C., and examined at the dates indicated] [a]

Sample No.	Type	Quality	Bacteria on plain agar held at—		Colon group	Bacteria on BCP [b] agar held at 20° C. for 4 days	
			20° C. for 4 days	37° C. for 2 days		Total	Acid
	July 11, 1922 (start):						
1	Whole	Good	350	175	0	370	30
2	Yolk	do	550	235	0	530	50
3	Whole	Heated	2,900	225	100	3,400	900
4	Yolk	do	1,025	75	0	1,130	0
5	Whole	Rotten	250,000	177,000	0	280,000	170,000
6	Do	do	235,000	385,000	0	970,000	200,000
	October 30, 1922:						
1	Whole	Good	355	240	0	280	0
2	Yolk	do	530	325	0	470	0
3	Whole	Heated	4,250	480	0	3,200	0
4	Yolk	do	9,350	175	0	2,300	0
5	Whole	Rotten	95,000	93,000	0	86,000	0
6	Do	do	430,000	350,000	0	235,000	0
	May 7, 1923 (37° C. for 2 days):						
1	Whole	Good	300	235	0	210	30
2	Yolk	do	490	245	0	150	0
3	Whole	Heated	1,400	700	0	440	220
4	Yolk	do	780	100	0	40	0
5	Whole	Rotten	41,000	42,000	0	32,000	11,000
6	Do	do	146,000	118,000	0	108,000	78,000

[a] The samples used in this experiment were dried by the spray process.
[b] Brom cresol purple lactose agar.

TABLE V.—*Effect of storage on bacterial counts of dehydrated eggs*

[Samples held in sealed bottles at 37° C., and examined at the dates indicated] [a]

Sample No.	Type	Quality	Bacteria on plain agar held at—		Colon group	Bacteria on BCP [b] agar held at 20° C. for 4 days	
			20° C. for 4 days	37° C. for 2 days		Total	Acid
	July 11, 1922 (start):						
1	Whole	Good	350	175	0	370	30
2	Yolk	do	550	235	0	530	50
3	Whole	Heated	2,900	225	100	3,400	900
4	Yolk	do	1,025	75	0	1,130	0
5	Whole	Rotten	250,000	177,000	0	280,000	170,000
6	Do	do	235,000	385,000	0	970,000	200,000
	October 31, 1922:						
1	Whole	Good	235	215	0	190	0
2	Yolk	do	610	230	0	470	0
3	Whole	Heated	2,300	130	0	1,600	0
4	Yolk	do	540	65	0	430	0
5	Whole	Rotten	7,500	7,500	0	6,000	0
6	Do	do	81,000	86,000	0	70,000	0
	May 7, 1923 (37° C. for 2 days):						
1	Whole	Good	300	115	0	80	20
2	Yolk	do	530	100	0	150	0
3	Whole	Heated	335	35	0	60	30
4	Yolk	do	130	20	0	0	0
5	Whole	Rotten	600	1,250	0	700	0
6	Do	do	1,350	1,300	0	1,400	300

[a] The samples used in this experiment were dried by the spray process.
[b] Brom cresol purple lactose agar.

The results reported in Tables III, IV, and V show that the number of viable organisms generally decreases as a result of storage. The extent of this decrease was studied in relation to the quality of the egg, the length of time in storage, and the temperature of storage. Good egg shows a much smaller decrease than poor material. Egg stored at a high temperature, or for a long time, loses a larger percentage of viable organisms than egg stored at a lower temperature or for a shorter time.

There was no visible deterioration in the product, but a distinct odor suggesting rancidity developed in all samples. This odor was most pronounced in the product made from low-grade eggs and held at the highest temperature.

The total colony count of the product made from good eggs remained practically stationary over a period of 10 months. The reason for this result is evident when the type of surviving organism is considered. The greater number of organisms which survived the heating process were spore formers. Furthermore, the spores did not germinate during the storage period, probably because the water content was too low, but they did not die during that period. Consequently, the count was an enumeration of the viable spores at each examination. In the samples of breaking stock having a high total count, however, many more of the nonsporulating organisms survived the heating process. These samples, therefore, showed a reduction in the total bacterial count, as these forms died during storage.

The effect of storage on the specific counts was marked. Samples which showed organisms of the colon group at the time of drying did not show them at the end of three months. All these results on the colon group were based on 1 c. c. of the 1:10 dilution. The same results were obtained with the acid formers. These also were absent in 1 c. c. of the 1:10 dilutions at the end of three months. At the end of 10 months, counts of the acid formers were made on plates held at 37° C. instead of 20°. Evidently the change in the temperature of incubation was all that was necessary for a different group of lactose fermenters to develop. These figures, therefore, lose any comparative significance with the preceding determination.

CONCLUSIONS

The count of viable bacteria in freshly prepared dehydrated egg varies, in general, with the quality of the raw product and the method of dehydration. The counts in the product prepared from whole eggs by the spray process varied from 350 in the good egg to 1,160,000 in the spots. In the product prepared by the vacuum-drum process from whole egg the counts varied from 45,000 in the good egg to 2,400,000 in the rots. In general, the yolk showed a higher number than the whites from the same whole egg.

The plate count of spray-process dehydrated egg held in storage depends on the initial count, the length of time in storage, and the temperature of storage. An initial count of 350 in good egg decreased to 300 in 10 months when held at 37° C. and at 20°, while a count of 235,000 in rotten eggs decreased to 1,350 when held at 37°. In one sample of the rotten eggs held at 20° the count increased from

235,000 to 430,000 in three months. A second sample showed a decrease from 250,000 to 95,000 at the end of three months and a further decrease to 41,000 at the end of 10 months.

The odor which is characteristic of poor-quality eggs is lost to some extent during the dehydration process.

An odor similar to rancidity develops in egg powder held at the various temperatures. This odor was most pronounced in rotten eggs held at 37° C.

THE EFFECT OF LOW TEMPERATURES ON BRUCHUS OBTECTUS SAY, AN INSECT AFFECTING SEED[1]

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INTRODUCTION

The common bean weevil, *Bruchus obtectus* Say, has been the subject of considerable study. This is probably due to its economic importance and the fact that it is a fairly simple insect with which to work. It can be readily propagated in large numbers, ordinary laboratory conditions constitute a normal habitat, and there is freedom from complications due to periodicity in its life cycle.

The investigation presented here covers two phases. The first is concerned with the general phenomenon of supercooling and freezing, as found in *Bruchus obtectus*. Working along the lines suggested by Bachmetjew (*3*)[2], attention has been given to the individual freezing of larvae, pupae, and adults. The second phase deals with the control of this insect by means of low temperatures. It is generally known that temperatures such as obtain in midwinter in the Northern States are fatal to *Bruchus obtectus*. The upper limits of these temperatures have not previously been worked out, although data on the effect of continued cold storage on the bean weevil have been recently published (*10*).

REVIEW OF LITERATURE

Much of the earlier work on the freezing of living tissues was done by botanists. An admirable résumé and bibliography of that work, together with a summary of the latest work on freezing of plant tissues, is given by Rosa (*14*). The outstanding worker on the subject of vital temperature in insects is Bachmetjew (*1*, *2*). His first volume contains a review of the theories contributed up to his time, and then extensive data on supercooling and freezing considered from the standpoint of the following influences: Rate at which the insect was cooled, sex and development, hunger, repeating the act of cooling the lymph, lymph coefficient, and season. In an appendix at the end of his first volume is a figure of the apparatus used. His second volume was published later (1907) and gives but little attention to the subject of vital temperature.

Pirsch (*13*) reviews some of the earlier work on individual freezing of insect larvae, particularly with reference to bees. His citation includes references to the earliest users of the electrothermal method of taking insect temperatures.

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[2] Reference is made by number (italic) to "Literature cited," p. 181.

Hine (*7*) reports observations on the effect of freezing insect larvae. Those of *Bellura obliqua* were subjected to temperatures below 0° F. and revived. He records that larvae were frozen solid and could be snapped in two, but the pieces were alive when thawed out. He also records observations on tomato hawk moth larvae. Those that had pupuated before the first frosts came carried through normally; immature forms were frozen as the plant was frozen, those on the tips being killed with the first touch of frost while those on the lower parts of the plant were not killed until frost struck that part of the plant. Sir John Ross's account of his Arctic expedition is quoted by Hine. Ross records that *Larria rossi* withstood successive freezings of −40° F. Further references along the same lines are found in Houlbert (*8, p. 255*). This writer, quoting Justi, a worker in 1753, reports that larvae could be frozen so hard that they could be snapped in two like ice. If the frozen larvae were permitted to return to normal temperatures, then development proceeded normally.

Duval and Portier (*4*) found the temperature limits of *Cossus cossus* to be −22° C. They report larvae so hard as to be easily broken in two without water appearing at the point of section. They incline to accept Bachmetjew's conclusion that only the intercellular water freezes and the rest supercools.

The latest paper available to the writer is that of Knight (*9*) on the nature of the color pattern of *Perillus bioculatus* Fabr., which contains a table of data on the supercooling of that insect considered from the standpoints of season (involving the colloidal state of the lymph) and repetitions of freezing.

EXPERIMENTAL WORK ON SUPERCOOLING AND FREEZING

METHOD

The electrothermal method of taking individual temperatures was used. This method is described by Taylor (*17*), Harvey (*6*), and White (*18*). A portion of the apparatus is figured by Pirsch (*13*), but in the present study a mirror galvanometer was substituted. This provided an admirable indicator of high sensitivity. A modification of the method for taking individual temperatures will be described later.

In each case of individual freezing tabulated in Table I, a finely pointed thermocouple of constantan and copper was thrust into the insect at approximately the ventral middle. The temperature readings were taken at intervals while the insect was being cooled.

It was found best to avoid using thermocouples made of heavy wire, the best and most uniform results being obtained by the use of No. 36 wire. The only trouble encountered with this wire was short-circuiting due to the rapid wearing of the silk insulation. Erratic jumping of the galvanometer soon gave notice of this trouble. When heavy wire was used, even though it could be tapered to a very fine point by means of acid, considerable difference was found to persist between the temperature registered by the instrument and a control thermometer.

All the specimens used for individual freezing were taken from exactly the same environmental conditions, so that variables due to changes in environment were eliminated. The variables due to

stage (and therefore also probable differences in the colloidal character of the lymph) have been considered, as well as the influence of the rate at which the insect was cooled.

GENERAL DISCUSSION

The typical graph of an insect's reaction to temperature, both high and low, is given in great detail in Bachmetjew's second volume (*2*). Knight (*10*) gives a simplified graph, which includes the essential features with which the writer is concerned.

There is first a gradual lowering of the insect's temperature to a point designated by Bachmetjew as the "critical point." It is presumed that the freezing of the body fluids causes the typical rebound to a point which the same author calls the "freezing point of the lymph." Bachmetjew concluded that it was necessary to again cool the insect to its supercooling temperature, or "critical point," after the rebound had taken place, before death ensued. It has been the experience of the writer that one rebound was sufficient to cause death. This was also the experience of Pirsch (*13*) and Knight (*9*). Careful examination of the data on which Bachmetjew based his conclusions shows considerable discrepancy. If the freezing was hurried or incomplete it is possible that muscular contractions after the insect thawed out again might have given the impression that life still remained. The data presented in this paper show that there is also a distinct ante-mortem zone of muscular activity. From the purely physical standpoint it seems reasonable to conclude that crystallization results in a disruption of cell tissue which, while not necessarily fatal to a plant, is fatal to an insect. There is a possibility, however, that when a fairly large insect is frozen the disruption of cell tissue may be only local and not sufficient to cause death. This would be most likely in the case of an insect which has been impaled on a thermocouple point.

FREEZING EXPERIMENTS WITH BRUCHUS OBTECTUS

Table I gives the results obtained by freezing 25 individuals in each stage—adults, pupae, and larvae. The adults were taken out of the bean just previous to emergence. This stage was the most satisfactory from the experimental standpoint, since variables due to the more active metabolism, histolysis, and histogenesis, encountered in the more immature stages, were absent. The criterion of color was used to determine approximately the age of the pupae; the age of the larvae was determined by size.

TABLE I.—*Data on freezing of Bruchus obtectus*

UNEMERGED ADULTS

Temperature at start	Time taken to reach 0° C.	Time taken to reach supercooling point	Rate at which insect was cooled	Supercooling point	Rebound point	Remarks
° C.	*Seconds*	*Seconds*	*Degrees per minute*	*° C.*	*° C.*	
2	3	18	0.63	−9.50	−7.75	
18	19	35	.55	−8.75	−5.80	
15	19	35	.56	−9.00	−7.20	
5	8	29	.40	−8.40	−5.85	
7.5	14	36	.45	−10.00	−6.50	
5	7	32	.36	−9.00	−6.75	
0	-------	23	.41	−9.50	−5.00	
17	26	50	.46	−11.00	−7.25	
14	20	43	.35	−8.00	−4.25	
15	28	47	.39	−7.50	−3.75	
8	13	34	.37	−7.75	−4.30	
3	15	40	.32	−8.00	−4.75	
10	14	35	.36	−7.50	−3.75	
15	14	40	.44	−11.50	−8.50	
13	15	36	.41	−8.60	−4.80	
9	7	25	.47	−8.50	−3.75	
12	-------	38	-------	−7.75	−5.30	
8	6	19	.58	−7.60	−4.50	
10	13	38	.29	−7.75	−4.25	
1	2	6	1.81	−7.25	−6.50	
13	18	43	.38	−9.50	−5.75	
5	14	33	.38	−7.25	−4.00	
10	12	28	.45	−7.25	−3.50	
12	-------	16	-------	−8.75	−7.25	
9.5	9	32	.50	−11.50	−7.75	
Average	-------	-------	-------	−8.68	−5.55	

PUPAE

15	24	61	0.26	−9.50	−5.00	Cream-colored.
10	12	45	.29	−9.80	−5.25	Light brown; wings grayed.
8	11	33	.43	−9.50	−4.50	Do.
9	11	29	.46	−8.25	−3.75	Cream-colored.
15	15	40	.44	−11.00	−5.75	Do.
8	9	40	.38	−11.75	−6.00	Do.
10	14	36	.36	−8.00	−3.75	Cream-colored; wings grayed.
8	13	35	.36	−8.00	−4.00	Cream-colored.
10	15	37	.43	−9.50	−4.25	Do.
5	3	25	.44	−9.75	−5.00	Do.
0	-------	55	.23	−12.50	−6.25	Do.
−6	-------	23	.14	−9.25	−5.00	Red-brown; wings black.
12	17	45	.34	−9.60	−5.80	Cream-colored.
5	6	21	.52	−7.75	−4.80	Red-brown; wings grayed.
0	-------	28	.35	−9.70	−5.20	Cream-colored.
14	12	40	.32	−9.00	−5.75	Do.
8	18	40	.29	−6.50	−4.25	Red-brown; wings grayed.
10	25	57	.23	−7.25	−4.50	Cream-colored.
16	18	40	.39	−8.50	−5.25	Thorax black; wings black.
11	15	45	.33	−9.75	−6.75	Red-brown; wings gray.
16	20	40	.34	−6.75	−3.80	Cream-colored.
9	15	35	.35	−7.00	−4.50	Do.
−5	-------	15	.43	−11.50	−5.25	Do.
5	9	26	.53	−9.00	−6.75	Do.
0	-------	23	.50	−11.50	−7.00	Do.
Average	-------	-------	-------	−9.22	−5.12	

TABLE I.—*Data on freezing of Bruchus obtectus*—Continued

LARVAE

Temperature at start	Time taken to reach 0° C.	Time taken to reach supercooling point	Rate at which insect was cooled	Supercooling point	Rebound point	Remarks
°C.	Seconds	Seconds	Degrees per minute	°C.	°C.	
15	19	48	0.35	−10.20	−7.20	Less than quarter grown.
15	20	48	.34	−9.50	−5.50	Full grown.
−2.5	-------	24	.36	−8.75	−5.50	Half grown.
3	8	30	.28	−8.80	−5.25	Full grown.
1	2	27	.35	−8.75	−6.60	Do.
15	30	62	.25	−8.00	−4.00	Two-thirds grown.
−3	-------	33	.28	−9.20	−5.10	Half grown.
9	11	31	.42	−8.40	−4.40	Full grown.
12	24	54	.28	−8.30	−6.75	Quarter grown.
10	14	60	.29	−13.25	−9.75	One-third grown.
7	10	52	.29	−12.50	−11.00	Quarter grown.
11	12	32	.50	−10.00	−7.50	Two-thirds grown.
−3	-------	14	.66	−9.30	−5.25	Do.
15	23	50	.32	−8.75	−6.10	One-third grown.
7	11	31	.45	−9.00	−6.50	Full grown.
14	15	48	.30	−10.00	−7.25	Do.
19	39	70	.40	−12.50	−8.80	Do.
3	2	8	1.96	−11.75	−8.60	Quarter grown.
16	20	70	.24	−12.00	−6.10	Full grown.
19	9	26	.66	−11.25	−7.75	Do.
10	4	9	2.00	−10.00	−5.00	Two-thirds grown.
-------	3	5	1.92	−9.60	−4.50	Half grown.
18	5	10	2.05	−10.25	−7.75	Do.
19	5	10	1.80	−9.00	−6.00	Do.
-------	3	7	2.31	−9.25	−4.75	One-third grown.
Average	-------	-------	-------	−9.53	−6.52	

The averages in Table I are brought together here for convenience of reference:

	Adults	Pupae	Larvae
	°C	°C	°C
Supercooling point	−8.68	−9.22	−9.53
Rebound point	−5.55	−5.12	−6.52

This shows a progressive lowering of the supercooling point from adults to larvae. The differences between these are slight, and may find their explanation in the metamorphic differences existing between these three stages. It is interesting to note that the supercooling point is depressed in the purely vegetative larvae and is highest in the adult. It should be noted, however, that in the case of the unemerged adults much greater uniformity of development is found than in any of the more immature stages. These first named were all obtainable at a point just previous to emergence. The pupae on the other hand, presented variations due to differences in the progress of histolysis and histogenesis, while the larvae were in all stages of growth, from very small specimens just big enough to contain the thermocouple point to full-grown larvae full of fat body.

Reference to Figure 1, B, will show that while the general trend of the curve is similar to those of Figure 2, A and C, the points are more widely separated. This suggests that individual differences among pupae are due to differences in *kind* while those of the larvae are dif-

ferences in *degree*. Stated in another way, this means that the larval period is one in which accumulation of material of the same kind and with the same properties goes on from the first establishing of the larva within the bean to its final maturity as a larva, while with the pupa histolysis and histogenesis produce changes in the chemical and physical constituents of the body contents, these changes varying with the age of the pupa. With the advent of the adult these changes are completed and the short period of quiescence before emergence simply permits of a hardening process taking place whereby the chitin becomes hard and brittle.

EFFECT OF INJURY ON THE INSECT'S RESISTANCE

Early in the course of the work the question as to the effect of injury on the resistance of these insects was recognized. Practically all the work of previous authors has been done with the thermocouple method which involves piercing the insect. Is the vital temperature so recorded any index of the capacity of the insect to resist low temperature? In order to test this, quiescent adults, pupae, and larvae were removed from the beans and put into a gelatin capsule through which the thermocouple point was thrust. The specimens were then uninjured and were lying around the couple point. The method was then modified in order to secure more rigidity by taking a piece of glass tubing, blowing a bulb at the end and then making a small hole in the bulb. The thermocouple was then thrust down until it was almost to the bottom of the bulb and the insects placed down in the bulb and close to the couple point. When several insects are so placed it so happens that one of them will "rebound," but the heat given off will be dispersed and only a mere indication of the rebound will be recorded by the instrument. Rebound under these circumstances then is simply an indication that inoculation has taken place and the amount is not significant (Table II).

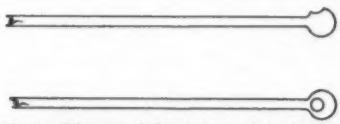


FIG. 1.—Diagram of glass tube used in freezing insects without injury due to piercing by thermocouple

TABLE II.—*Experiments to determine the effect of injury on an insect's resistance*

Supercooling point	Rebound point	Stage	Number used	Result
°C.	°C.			
−13.60	−10.70	Pupal	14	All died.
−17.00	None.	do	15	Lived.
−20.00	None.	do	3	Do.
−20.00	None.	do	3	Do.
−20.00	None.	do	3	Do.
−13.25	None.	Larval	1	Do.
−16.50	None.	do	1	Do.
−16.00	None.	do	1	Do.
−20.00	None.	do	24	Do.
−17.00	Slight.	do	4	Three lived.[a]
−15.50	None.	do	1	Lived.
−17.00	None.	Adult[b]	10	Seven lived.
−17.00	None.	do.[b]	15	Six lived.
−22.00	None.	do.[b]	10	One lived.

[a] Of these four larvae one was slightly injured putting it into the tube and a thin film of its body fluid held it to the glass. The couple was not touching it. Only that larva died; the other three lived.
[b] Unemerged adults.

Comparing these figures (Table II) with the averages for individual freezings quoted above, it becomes apparent that all these stages are capable of resisting lower temperatures when they are not injured. This may be due to the cuticula preventing the rebound or, in other words, preventing "inoculation." It may be that the presence of free water in the vicinity of the couple point may hurry inoculation in the case of the injured specimens. That an uninjured organism can better withstand extreme conditions than an injured one is a point that has been overlooked in much previous work.

When an insect is impaled on a thermocouple point and cooled, the temperature recorded is that of the lymph and broken-down tissue in the immediate vicinity of the point. It may be of some physiological significance that the freezing point of the impaled insect's lymph is not the same as that of the insect as a living uninjured organism.

The experiments described in the second part of this paper, when bean weevils in all stages were able to withstand temperatures as low as those shown to be the limit for injured specimens and for a greater length of time, seems to establish this point still further.

RELATION BETWEEN SUPERCOOLING AND REBOUND

Figure 2, A, B, and C, are dot charts wherein the supercooling temperatures have been plotted against the rebound points for each set of data on individual freezing. The charts suggest that there is a relationship between the two factors, so the Pearsonian method of arriving at the coefficient of correlation was used (*12*).

The correlations that exist between supercooling and rebound are thus found to be:

	Correlation	Probable error
Adults	+0.779	0.053
Pupae	+.614	.084
Larvae	+.890	.028

These high correlations indicate very definitely that the supercooling point bears a distinct relationship to the rebound point. Just what this relationship is, however, is another matter. According to chemical law (*11, pp. 172–180*) the rebound point should be the same no matter how low supercooling goes. If this law applies, then the explanation of this correlation must be sought elsewhere.

Knight (*9*) showed that when freezing *P. bioculatus* Fabr. a thermocouple placed near the insect registered a rise in temperature when the insect rebounded, showing that heat was given off to the surrounding air. This means, of course, that the thermocouple on which the insect is impaled does not register the total amount of heat of crystallization given off by the insect but that some is lost by radiation. These insects (*B. obtectus*) are very small, not more than 3 or 4 mm. long, so that their surface is very great in proportion to their mass. It follows then, that radiation to the air of the chamber must consume a considerable portion of the heat of crystallization.

Because radiation varies as the difference in temperature between the source of the heat and the surrounding medium, it is reasonable

to assume that the lower the temperature of the cooling chamber the more heat will be absorbed by radiation when the insect rebounds. The lower the insect supercools the lower will be the point to which the heat of crystallization available to the thermocouple will enable the temperature to rise, or, in other words, the lower will be the point of rebound. If this is true the correlation between supercooling and rebound points is simply due to the amounts of radiation being related to the temperature of the cooling chamber. Whatever the explanation may be, the fact of the existence of this correlation seems to have been demonstrated.

RELATION BETWEEN SUPERCOOLING AND THE RATE AT WHICH THE INSECT WAS COOLED

Bachmetjew expressed the belief that possibly there may be a relationship between the rate at which the insect is cooled and the supercooling point. His "abkuhlunggeswindigkeit" is described as a "shadow in the background."

Figure 3, A, B, and C, are dot charts wherein the supercooling points have been plotted against the rate at which the insect was cooled. In computing these rates the time taken to bring the insect from 0° C. to the supercooling point was used in order that the rates could all be calculated from a common starting point, as the initial temperature of the bath varied. The coefficients of correlation and the probable errors for the three stages are as follows:

	Coefficients	Probable errors
Adults	−0.095	0.138
Pupae	− .100	.129
Larvae	+ .015	.134

It is thus seen that the rate of supercooling has no part in establishing the temperature of supercooling; the coefficient is less in each case than the figure required to establish even a bare relationship. It might be added here that the data for larvae offer the best opportunity for verifying this phase of the question. Previous to obtaining the latter half of these data the suction of an ordinary tap pump was used to cool the ether, and differences in rate were slight. Later, a suction pump was obtained which reduced temperature very rapidly, so that there is a much greater variation in the rates.

EXPERIMENTS ON THE UPPER LIMITS OF LOW TEMPERATURES FATAL TO BRUCHUS OBTECTUS SAY

HISTORICAL

Garman (*5*) subjected weevils to outside temperatures. These are presumably mean temperatures for the periods stated. His general conclusion was that a temperature of about 0° F. for a period of 24 hours was a complete control. According to the data of this paper the eggs are most resistant and the larvae least resistant. This writer suggests that the reason for the freedom of Canadian-grown seed from infestation is due to the inability of the weevils to survive the rigor of the winter. Sanderson (*15*, *16*) discusses this subject in some detail for insects generally.

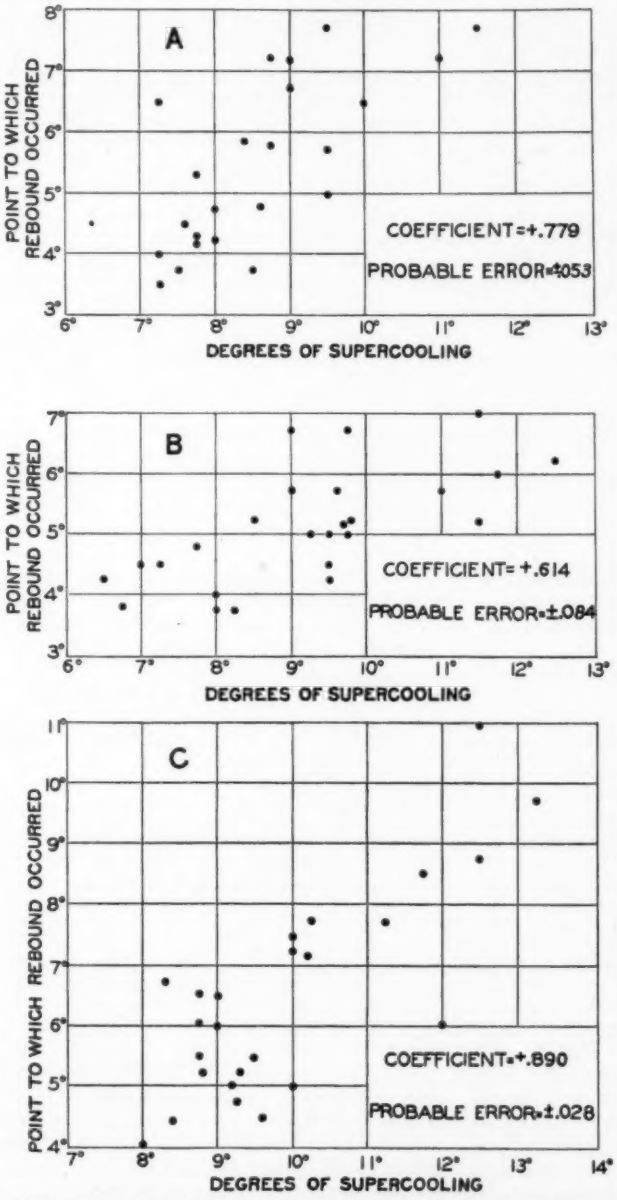


FIG. 2.—Relation between supercooling and rebound. A, adults; B, pupae; C, eggs

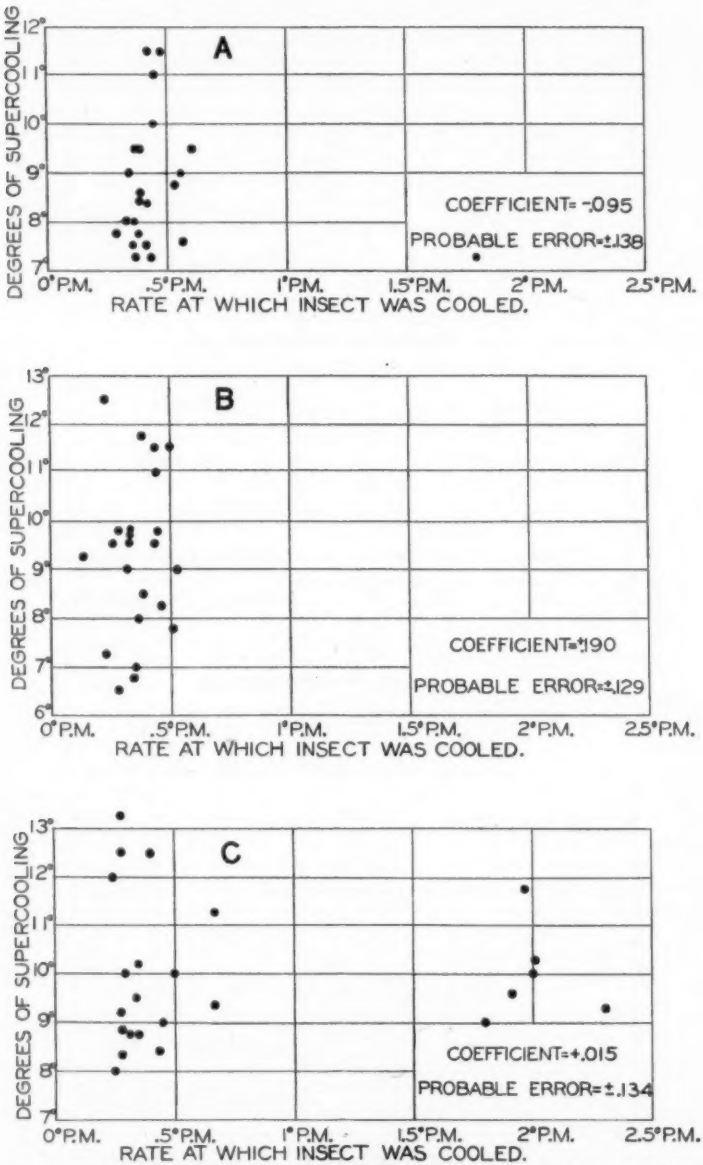


FIG. 3.—Relation between supercooling and the rate at which insect was cooled. A, adults; B, pupae; C, larvae.

Larson and Simmons (*10*) conducted an extensive series of experiments with commercial cold-storage conditions. They used three temperatures, 36, 32, and 20° F. Perfect control of the weevil infestation was obtained with 56 days' exposure to 32°. Loss of reproductive power was noted after exposure for 22 days or longer. Satisfactory control was obtained with 66 days' exposure at 36°. Unemerged adults were found to be the most resistant, pupae next, and larvae the least resistant. No experiments with eggs of *Bruchus obtectus* are recorded. It is suggested that weevils put into cold storage from lower temperatures obtaining in February could resist longer than those put in at the higher temperatures of November.

De Ong (*3*) used several species of insects in a study of cold-storage control. His findings are interesting here in that he reports that mature larvae were more resistant than any other stage studied. He also doubts the mortality of the egg at temperatures fatal to other more advanced stages.

METHOD

In these studies a constant-temperature cabinet was used with which it was possible to keep temperatures within less than 1° of the desired temperature for long periods. Glass vials containing beans infested with the several stages of weevil were placed in this cabinet and subjected to the temperatures as stated in the tables for the several periods.

A difficulty experienced in dealing with the immature stages of bean weevil infestation is that of knowing just which stage was being dealt with when the cavity first became visible from the outside of the bean. The cavity may contain either a pupa, prepupa, or even a larva. Another difficulty is in the fact that when beans are heavily infested with weevils in all stages the last larvae to enter the bean often perish through lack of food. This act rather tends to stress a larval mortality which may not be due to the conditions of the experiment. In order to avoid this colonies of known data were used for getting definite data on larvae. The most complete data, however, have been obtained from the use of beans where the weevils were showing black through the bean—in all cases unemerged adults—and those where the work of the weevil was visible from the outside, but the weevils were still cream-colored. The majority of these were early pupae, but larvae were sometimes found within these light-colored cells.

EFFECT OF FATAL TEMPERATURE ON THE APPEARANCE OF THE SEVERAL STAGES.

Eggs shrivel up and the contents become clear. It is not always easy to ascertain whether the eggs were killed by the temperature or were simply infertile. For this reason total mortality and hatching have been the criteria used. Pupae when fatally affected turn rotten and brown. The same is true of larvae. With unemerged adults later emergence was the criterion, and for active adults recovery.

An interesting condition met with was that called, for want of a better name, "arrested development." In this condition development proceeds for some time after return to normal temperatures, but the insect fails to mature and usually fails to complete the stage in which it was at the time of freezing. Pupae often continue their development until they are almost to the unemerged or quiescent

stage. The head and thorax and appendages can become complete, but the abdomen usually remains cream-colored, the insect dying at that point.

Unemerged adults show another phase of this condition. Normally the emerging beetles cut clean circles in the epidermis of the bean, but the treated unemerged adults lose the capacity to do this and endeavor to emerge by pushing through the center of the circle. They are found dead with part of the mouth parts showing through. In the upper limits of the zone of arrested development adults will continue development quite normally if assisted out of the bean. The effect here, then, seems to be an inhibiting of the normal response of the insect, resulting in death by imprisonment.

EXPERIMENTS ON TEMPERATURES FATAL TO B. OBTECTUS

Table III gives the results of experiments on the several stages, and following it are Figures 4, 5, and 6, in which the data of the experiment have been incorporated. The table has been condensed, but all the data are given in the figures.

TABLE III.—*Limits of fatal temperature-time zones of Bruchus obtectus*

ACTIVE ADULTS

Temperature	Time	Result	Temperature	Time	Result
°C.	*Hours*		°C.	*Hours*	
−2	168	Lived.		1	8 lived; 13 killed.
	24	Do.		2	Muscular activity, then death.
−7	36	Do.	−14	3	Do.
	48	1 lived.		4	Killed.
	24	Lived.		5	Do.
−8	30	Killed.	−20	2	Do.
	36	Do.		3	Do.
−9	1	Lived.			
	.5	Do.			
	1	Do.			
	2	18 lived; 10 killed.			
−10	3	Muscular activity, followed by death.			
	4–11	Do.			
	12	Killed.			
	13	Do.			

UNEMERGED ADULTS

−8	24	Lived.	−14	1	Lived.
	36	Killed.		2	Killed.
−10	1	Lived.	−17	24	Do.
	2–6	Do.	−20	.25	Killed.
	7	Killed.		.50	Do.
	8	Do.			

PUPAE AND ADVANCED LARVAE

−2	168	Lived.	−14	1	Lived.
	24	Do.		3–9	Killed.*
	36	Do.	−17	24	Do.
−8	48	1 lived.		36	Do.
	56	Killed.*		.5	Lived.
	60	Do.	−20	2	Killed.*
−9	1	Lived.		4	Do.
	1	Do.		6	Do.
	3–7	Do.			
	8	Killed.*			
−10	9–16	Do.			
	22–23	Do.			
	25–30	Do.			
	32–34	Do.			

* Cases where death followed post-freezing development.

TABLE III.—*Limits of fatal temperature-time zones of Bruchus obtectus*—Con.

LARVAE OF KNOWN AGE

Temperature	Time	Result	Temperature	Time	Result
°C.	Hours		°C.	Hours	
−2	168	Lived.	−14	2	Killed.
−8	36	Killed.	−17	56	Do.*
−9	1	Do.	−20	24	Do.

EGGS

−7	24	Hatched.	−17	56	Killed.
	48	Do.		48	Do.
−8	56	Do.		1	Hatched.
	60	Killed.	−20	4	Do.
−10	4	Hatched.		5	Killed.
	16	Do.			
	2	Do.			
	5	Killed.			
−14	6	Hatched.			
	6	Killed.			
	7	Do.			

* Cases where death followed post-freezing development.

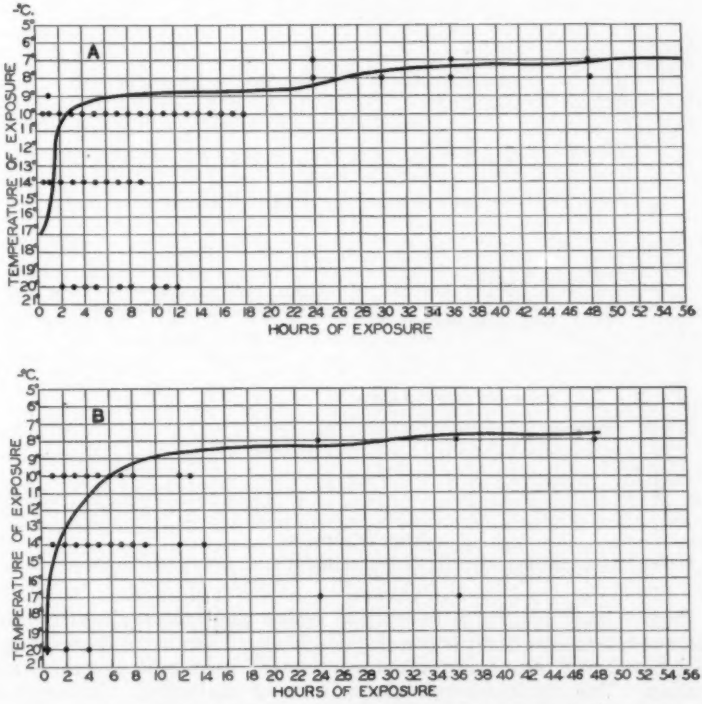
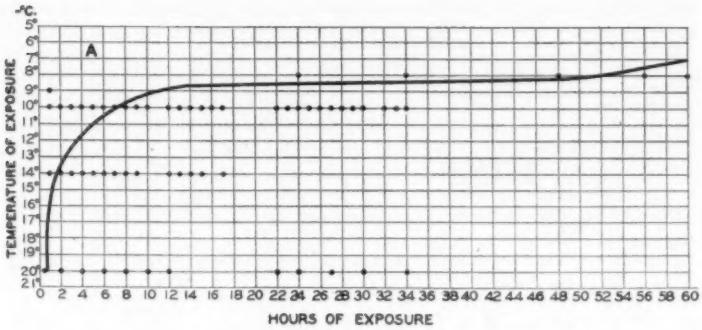


FIG. 4.—Limits of fatal temperature-time zone. A, active adults; B, unemerged adults



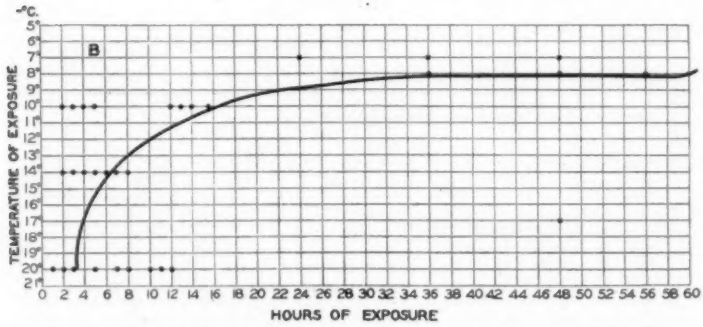


FIG. 5.—Limits of fatal temperature-time zone. A, pupae and advanced larvae; B, eggs

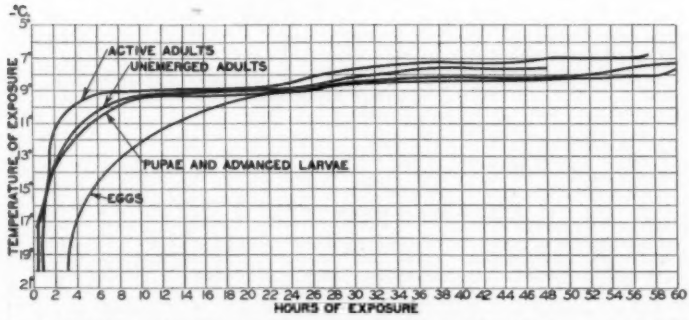


FIG. 6.—Fatal temperature-time zones for *Bruchus obtectus* Say. Active adults; unemerged adults; pupae and advanced larvae; eggs

From these data it is seen that active adults are slightly more susceptible to low temperatures. Unemerged adults and the stages designated as "pupae and advanced pupae" have curves practically similar. The slight difference is in favor of the latter. The eggs of *Bruchus obtectus* can apparently withstand lower temperatures than any other stage. With respect to eggs, however, the criterion used

was whether or not the eggs hatched, not the ultimate development of the insect.

These data further show that at temperatures down to −8° C. a much greater length of time must elapse before fatal results ensue. At that temperature all the curves flatten out at about the 24-hour period. In passing it should be noted that this temperature is approximately the one to which injured specimens supercool in the ether bath used in the electrothermal method.

The highest temperature used, −2° C. for one week, was not fatal to any stage, and Larson and Simmons (*10*) have shown that a much longer period than one week is necessary at 0° C. to insure a complete kill. The curve showing the limits of the fatal temperature-time zone is therefore very long and with a very gradual slope in the upper 8 degrees of below 0° C. temperature.

It is evident, however, that for lower temperatures a much shorter time is necessary. Referring to the curves again, it is seen that there was no survival at an exposure of −20° C. for a period of five hours, and even this period applies only to the hatching of eggs. Unemerged adults and pupae could withstand only a very short period at this temperature, probably only that period required to permit penetration of the temperature into the bean. Adults died at an exposure of −17° for less than one hour, while one hour at −14° was fatal to them.

From Table III it is seen that pupae and advanced larvae continue their development even after considerable periods of exposure. This is of much interest from the standpoint of physiology, but since such development does not continue long enough to permit the emergence of the insect, the curve has been drawn between the last points of survival and the first points indicating death without regard to whether there was any period of later development or not.

The data for larvae of known age are not as complete as those for the other stages. Table III indicates, however, that the mortality zone is the same as for unemerged adults and pupae and advanced larvae. As sets of vials containing larvae of several ages were used each time, it was possible to show that there was no difference in power of reistance between very young larvae and those that were well advanced, so that the mortality zone for pupae and advanced larvae can safely be applied to larvae of less development.

Larson and Simmons (*10*) suggest that the temperature at which the colony of weevils was maintained prior to freezing has some effect on resistance. To verify this a colony was maintained at approximately 0° C. for one week in a commercial cold-storage plant. At the end of this time adults, unemerged adults, and pupae were subjected to a temperature of 14°. The results indicate that no hardening had taken place. Both active and unemerged adults were killed by exposure for one hour, while exposures of two hours killed the pupae and advanced larvae. An exposure of seven hours killed pupae and advanced larvae at −10°. These results are essentially the same as with weevils taken from room temperatures.

SUMMARY

The common bean weevil, *Bruchus obtectus*, Say, has been used for experiments on supercooling and resistance to low temperature. Bachmetjew (*2*) has made the most extensive contributions to the subject of vital temperature in insects, and this study follows in a general way the lines laid down by him. While he believed that an insect's temperature must be lowered again to its supercooling point after a rebound has taken place before death ensued, subsequent works show that an insect is killed if a rebound occurs. A rebound is evidence that heat of crystalization is given off. Crystalization of the lymph is believed to be responsible for the death of the insect.

Comparing differences between individuals, it is found that pupae show more variation from the average trend. This is explained in the fact that pupae of all ages were used, and the physical properties of their lymph varied.

It has been seen that larval, pupal, and adult weevils could withstand lower temperatures when cooled uninjured than when the point of a thermocouple was thrust into them. Active adults withstood temperatures of −10° C., a temperature below the average supercooling point, for a period of three hours. Pupae and advanced larvae withstood the same temperatures for seven hours.

It has not been found possible to obtain the exact freezing point of *Bruchus obtectus* with present-day electrothermal methods.

There is a distinct correlation between the supercooling point and the rebound point, but this is believed to be due to radiation from the insect to the air of the cooling chamber. The exact freezing point is actually much higher, then, than the rebound points recorded.

The temperature-time experiments show that time is a factor in the resistance of *Bruchus obtectus* to low temperature. It is apparent, with freezing points as high as those of this insect must be, that supercooling takes place at temperatures of −10° C. or below. That being the case, the data imply that supercooling is possible for limited times only at certain temperatures.

The relationship between supercooling and the rate at which the insect has cooled has been studied. There seems to be no correlation between these two factors.

A condition of post-freezing development with ultimate death has been observed at temperatures just below the limits of resistance. This has been referred to in this paper as "arrested development." It manifests itself in the adults as failure to emerge, due to the loss of the insect's capacity to cut its way out of the bean; pupae can metamorphose only to adult form in the head and thoracic regions, the abdomen remaining undeveloped; larvae are unable to emerge from the egg, or, if they do emerge, it is often through the side of the egg, not through the operculum. Many that emerge from the egg are unable to enter the bean.

The limits of the fatal temperature-time zones have been determined for four stages of *Bruchus obtectus*. This insect apparently has no capacity for hardening.

The thermal constant, as described by Sanderson and Peairs (*16*), has not been worked out for this insect. A difference of less than 10° F.—the difference obtaining between the temperature of the laboratory and a cool, dry basement at about 64°—almost doubles the

length of time required for a complete life cycle. This means that even in the South development of the insect could be retarded considerably until fatal outdoor temperatures prevailed.

CONCLUSIONS

Bruchus obtectus Say dies if the heat of crystallization is given off. A definite correlation exists between supercooling and rebound, which is believed due to radiation. The electrothermal method does not give the true freezing point of an insect because of radiation and the effect of injury on the insect. There is no correlation between supercooling points and the time required to bring the insect to these points.

The capacity of *Bruchus obtectus* to resist low temperature is limited by the length of time it can remain in the supercooled condition. This capacity varies with the stage, active adults being least resistant and eggs most resistant.

Growth of *Bruchus obtectus* in beans can be materially retarded by storage in temperatures even as high as 64° F. Temperatures of below −10° C. for a period of 12 hours are fatal to all stages of this insect.

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THE INFLUENCE OF IRRIGATION WATER AND MANURE ON THE COMPOSITION OF THE CORN KERNEL[1]

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INTRODUCTION

The total ash, calcium, magnesium, potassium, and phosphorus content of wheat, oats, and barley has been found to increase directly with the increase in quantity of irrigation water applied during the growing period (*5*).[2] This has been interpreted as being due to the increased bacterial activity resulting from an optimum moisture content (*4*) which would render available greater quantities of these specific elements to the growing plants. To test this theory, and also to obtain information concerning the composition of corn grown on highly calcareous soil, the work here reported was undertaken.

EXPERIMENTAL DATA

SOIL

The corn was grown on the Greenville Experiment Farm, the soil of which is of a sedimentary nature and contains large quantities of calcium and magnesium, probably in the form of dolomite. In chemical and physical composition it is very uniform to a great depth. The chemical and physical analyses of the soil are given in Table I. The chemical analyses were made according to the official methods of the Association of Official Agricultural Chemists (*1*), and the physical analyses were made by means of the Yoder (*9*) soil elutriator.

TABLE I.—*Chemical and physical composition of the soil of the Greenville experiment farm, North Logan, Utah*

Chemical composition		Physical composition	
Constituent	Per cent	Constituent	Per cent
Insoluble residue	41.46	Coarse sand	0.21
Soluble silica	.62	Medium sand	9.63
Total	42.08	Fine sand	30.04
Potash (K_2O)	.67	Coarse silt	32.25
Soda (Na_2O)	.35	Medium silt	12.30
Lime (CaO)	16.88	Fine silt	6.25
Magnesia (MgO)	6.10	Clay	7.63
Oxide of iron (Fe_2O_3)	3.06	Moisture	1.60
Alumina (Al_2O_3)	5.64	Soluble and lost	.10
Phosphoric acid (P_2O_5)	0.41	Specific gravity	2.67
Carbon dioxide (CO_2)	19.82	Apparent specific gravity	1.23
Volatile matter	5.6	Water-soluble salts	.06
Total	100.69		
Humus	.53		
Nitrogen	.14		

[1] Received for publication Oct. 14, 1924; issued September, 1925.
[2] Reference is made by number (italic) to "Literature cited," pp. 189.

The physical and chemical composition of this soil is quite uniform to a depth of 10 feet. The soil is exceptionally rich in phosphorus and potassium, but low in nitrogen and humus. The calcium and magnesium contents, mainly in the form of dolomite, are exceptionally high. The soil is especially fertile when supplied with optimum moisture and organic matter.

MANURE AND IRRIGATION

The plats on which the corn was grown were 7 feet wide and 24 feet long with a 4-foot walk dividing them. The land was plowed in the fall and left in that condition until spring when a mixture of fairly well-rotted horse and cow manure was applied to the various manured plats. In each ton of manure applied there were approximately 738 pounds of dry matter, 3.04 pounds of phosphorus, 13.7 pounds of potassium, and 16.08 pounds of nitrogen. The manure was thoroughly disked or plowed into the soil. Measured quantities of irrigation water were applied to the various plats as follows:

4 plats received no water and no manure.
2 plats received 5 inches of water and no manure; water applied in 2 equal applitions.
2 plats received 10 inches of water and no manure; water applied in 2 equal applications.
2 plats received 20 inches of water and no manure; water applied in 4 equal applicatons.
2 plats received 30 inches of water and no manure; water applied in 6 equal applications.
2 plats received 40 inches of water and no manure; water applied in 8 equal applications.

On a duplicate series of plats, manure was applied at the rates of 5 and 15 tons to the acre, the application of water being the same in every way as that on the unmanured plats. Hence the corn was grown on soils (1) without manure, (2) with 5 tons of manure to the acre, and (3) with 15 tons to the acre. The water applied varied from none to 40 inches, both with and without manure. However, this does not represent the total water reaching the soil, for there was an annual average precipitation of about 18 inches which was the same for all plats.

The irrigation water contained in each million parts 144 parts of calcium carbonate, 78 parts of magnesium bicarbonate, 3 parts of magnesium chloride, 7 parts of magnesium sulphate, 8 parts of sodium bicarbonate, 2 parts of sodium sulphate, and 2 parts of sodium chloride. Each acre-foot of the water carried to the soil 2.2 pounds of potassium, 0.005 pound of phosphorus, and 1.1 pounds of sodium nitrate. Analyses of the soil showed that during the course of the experiment, little of the nitrogen (*7*) and phosphorus was being leached from the soil, but large quantities of the calcium magnesium and organic matter were disappearing. The analyses of the corn were made on composite samples taken from the various plats receiving the same treatment and from the 12 yearly yields from 1911 to 1922. The analyses were all made in duplicate according to the official methods (*1*).

NITROGEN

The percentage composition of the dry corn kernel and the pounds per acre of nitrogen in the grain receiving various manure and irriga-

tion treatments are given in Table II. In these results all grain grown without irrigation water and with the various manurial treatments is averaged together. Likewise, all the corn grown without manure and with varying irrigation treatments has been analyzed separately and then averaged in the table. Hence the results in all the tables represent the average analyses of the 12 years of corn and duplicate analyses from the grain grown on 12 different plats. Therefore the figures given should represent quite accurately the composition of the grain grown with these different treatments during the past 12 years.

TABLE II.—*Percentages and pounds per acre of total nitrogen in the corn kernel grown with varying quantities of irrigation water and manure*

Treatment	Nitrogen	Nitrogen per acre	Treatment	Nitrogen	Nitrogen per acre
	Per cent	*Pounds*		*Per cent*	*Pounds*
No irrigation water [1]	2.07	78.71	40 inches irrigation water [1]	2.03	90.81
5 inches irrigation water [1]	2.04	91.34	No manure [2]	1.94	70.29
10 inches irrigation water [1]	2.02	84.96	5 tons manure [2]	2.07	95.09
20 inches irrigation water [1]	2.07	98.17	15 tons manure [2]	2.13	102.63
30 inches irrigation water [1]	1.99	92.05			

[1] And varying quantities of manure. [2] And varying quantities of irrigation water.

In these results there appears to be little difference in the nitrogen content of the corn kernel with varying quantities of irrigation water applied during the growing season. This is due to the manure, as an examination of the results from which the averages in the above table were obtained reveals the fact that the corn grown with no irrigation water contained 9 per cent more nitrogen than did that grown with 40 inches of water. The nitrogen content of the corn increases progressively with the manure applied. Therefore the nitrogen content of grain depends on the quantity of available nitrogen in the soil. Although up to a certain point the speed with which nitrogen is made available is dependent upon the moisture content of the soil (*4*), the quantity which remains within the feeding area of the plant rather rapidly decreases as the water applied increases, because of its great solubility (*3*). Therefore the high protein content of dry-farm grains is due to two factors: (1) The storage of two years' nitrogen in the surface soil due to summer-fallowing (*3*); (2) the scant rainfall permitting the nitrates formed to remain and through upward capillarity to be concentrated in the surface-foot sections. Hence the nutrient media on which the plant is feeding is high in nitrates and the plant consequently builds protoplasm having a high nitrogen concentration.

Slightly larger quantities of total nitrogen are removed in the corn kernel from the irrigated soil than from the nonirrigated. However, there is no uniformity in the results in this respect. The grain grown on the manured soil, on the other hand, shows a relationship between the nitrogen applied and that removed in the crop. Thirty-one per cent of the added nitrogen was accounted for in the corn kernel grown on the soil receiving 5 tons of manure yearly, and only 14 per cent where 15 tons to the acre were applied; but the excess applied in the 15-ton application accumulates (*6*) in the soil, and if the soil is not manured for a number of years it yields much of this remaining nitrogen to the grain grown later.

ASH

The average percentage composition and pounds to the acre of total ash in the corn kernel grown with varying quantities of irrigation water and manure are given in Table III.

The corn kernel grown with 40 inches of irrigation water contains 8 per cent more ash than the corn kernel grown with no irrigation water, but the ash is as high with 10 inches of water as with 40. The ash content is highest where the soil receives enough moisture to promote maximum bacterial activity with the resulting liberation of the maximum of plant food.

TABLE III.—*Percentages and pounds per acre of total ash in the corn kernel grown with varying quantities of irrigation water and manure*

Treatment	Ash	Nitrogen per acre	Treatment	Ash	Nitrogen per acre
	Per cent	*Pounds*		*Per cent*	*Pounds*
No irrigation water [1]	1.65	62.46	40 inches irrigation water [1]	1.79	76.79
5 inches irrigation water [1]	1.66	74.05	No manure [2]	1.65	58.96
10 inches irrigation water [1]	1.79	75.39	5 tons manure [2]	1.75	82.20
20 inches irrigation water [1]	1.78	81.73	15 tons manure [2]	1.76	84.74
30 inches irrigation water [1]	1.76	81.39			

[1] And varying quantities of manure. [2] And varying quantities of irrigation water.

That it is the available plant food which determines the ash content of the grain is well brought out by the results with the manurial treatments. The grain grown on soil receiving 5 tons of manure per acre yearly contains 6 per cent more ash than corn grown under similar conditions but receiving no manure. That grown on soil receiving 15 tons of manure yearly contains only slightly more ash than that grown with 5 tons of manure.

The quality of ash in the corn kernel removed from the soil increases as the water applied increases up to 20 inches; above this there is a decrease. That removed by the plant markedly increases with increase in manure.

PHOSPHORUS

The phosphorus content of the corn kernel increased progressively with the irrigation water applied (Table IV). The kernel of copiously irrigated corn contained more than 9 per cent more phosphorus than did that of the unirrigated. The percentage might have been still higher if greater quantities of water had been applied (*5*). Unirrigated corn has been found to be higher in phosphorus than unirrigated wheat, oats, or barley. However, irrigated wheat, oats, and barley were higher in phosphorus than the highly irrigated corn. The increase due to the use of manure is very small.

With one exception the quantity of phosphorus removed from the soil by the corn grain increased as the water applied increased up to 30 inches. The quantity removed from the manured plats increased as the manure applied increased. The increase due to manure was greater than the increase due to water. The lowest phosphorus content of the corn kernel, as grown on this soil, is 29 per cent higher than the average reported by Hopkins (*8, p. 603*) after von Wolff; the highest is 42 per cent higher than the average of von Wolff. These results and those previously published (*5*) make it certain that

grains grown on this soil are exceptionally rich in phosphorus and that the phosphorus content of grain is increased by irrigation water, the increase being due primarily to a greater supply of available phosphorus.

TABLE IV.—*Percentages and pounds per acre of total phosphorus in the corn kernel grown with varying quantities of irrigation water and manure*

Treatment	Phosphorus	Phosphorus per acre	Treatment	Phosphorus	Phosphorus per acre
	Per cent	*Pounds*		*Per cent*	*Pounds*
No irrigation water [1]	0.32	12.12	40 inches irrigation water [1]	.35	15.54
5 inches irrigation water [1]	.33	14.50	No manure [2]	.33	11.84
10 inches irrigation water [1]	.33	13.69	5 tons manure [2]	.34	16.02
20 inches irrigation water [1]	.33	15.95	15 tons manure [2]	.33	16.11
30 inches irrigation water [1]	.35	16.13			

[1] And varying quantities of manure. [2] And varying quantities of irrigation water.

CALCIUM

The calcium content of the same grain is given in Table V.

TABLE V.—*Percentages and pounds per acre of calcium in the corn kernel grown with varying quantities of irrigation water and manure*

Treatment	Calcium	Calcium per acre	Treatment	Calcium	Calcium per acre
	Per cent	*Pounds*		*Per cent*	*Pounds*
No irrigation water [1]	0.13	4.77	40 inches irrigation water [1]	0.14	6.09
5 inches irrigation water [1]	.18	8.08	No manure [2]	.14	4.81
10 inches irrigation water [1]	.18	7.01	5 tons manure [2]	.15	6.12
20 inches irrigation water [1]	.14	6.89	15 tons manure [2]	.15	8.15
30 inches irrigation water [1]	.14	5.31			

[1] And varying quantities of manure. [2] And varying quantities of irrigation water.

The percentage of calcium in the corn kernel increases with the irrigation water applied up to 10 inches yearly; above this it gradually decreases. Corn grown with 10 inches of irrigation water contains 40 per cent more calcium than corn grown without irrigation water; that receiving 40 inches of irrigation water contains only 8 per cent more calcium. Manure also increases the calcium content of the corn, but not to the same extent as does irrigation.

The calcium-low corn in this series contains about six times the quantity reported by Hopkins (*8, p. 603*), whereas the calcium-rich corn contains nearly nine times the amount. Differences such as this must be of great significance in animal nutrition. Moreover, the calcium-phosphorus ratio changes with the application of irrigation water. In the corn grown with irrigation water the calcium-phosphorus ratio is 1: 2.5, that grown with 10 inches of irrigation water is 1: 1.8, whereas that grown with 40 inches has a ratio of 1: 2.6. The application of manure also narrows the calcium-phosphorus ratio. It appears from these results, viewed from the standpoint of the mineral elements, that corn grown on this soil with 10 inches of irrigation water is the most valuable from the viewpoint of the nutrition of animals.

MAGNESIUM

The average magnesium content of the same corn is given in Table VI.

TABLE VI.—*Percentages and pounds per acre of total magnesium in the corn kernel grown with varying quantities of irrigation water and manure*

Treatment	Magnesium	Magnesium per acre	Treatment	Magnesium	Magnesium per acre
	Per cent	*Pounds*		*Per cent*	*Pounds*
No irrigation water [1]	0.20	7.57	40 inches irrigation water [1]	0.20	8.92
5 inches irrigation water [1]	.20	9.59	No manure [2]	.19	6.72
10 inches irrigation water [1]	.20	7.98	5 tons manure [2]	.22	10.11
20 inches irrigation water [1]	.20	9.65	15 tons manure [2]	.21	9.58
30 inches irrigation water [1]	.21	9.12			

[1] And varying quantities of manure. [2] And varying quantities of irrigation water.

The magnesium content of the corn is nearly constant with all water treatments. The magnesium content of this corn is nearly twice that reported by von Wolff (*8, p. 603*). Even with the high magnesium content of this grain grown on unmanured soil, manured grain shows a gain in magnesium content of 15 per cent.

The calcium-magnesium ratio of corn is 1: 1.37. The total quantity of calcium and magnesium removed from the soil increases with the irrigation water and manure applied. The results all tend to bear out the theory that the change in the composition of the grain is due primarily to an increased available supply of plant food resulting from increased bacterial activity. This in turn is a function of the moisture and organic content of the soil (*2, 4*).

POTASSIUM

The potassium content of the corn kernel is given in Table VII.

TABLE VII.—*Percentages and pounds per acre of total potassium in the corn kernel grown with varying quantities of irrigation water and manure treatment*

Treatment	Potassium	Potassium per acre	Treatment	Potassium	Potassium per acre
	Per cent	*Pounds*		*Per cent*	*Pound*
No irrigation water [1]	0.37	14.62	40 inches irrigation water [1]	0.41	18.09
5 inches irrigation water [1]	.39	16.42	No manure [2]	.38	13.46
10 inches irrigation water [1]	.40	16.60	5 tons manure [2]	.39	18.27
20 inches irrigation water [1]	.40	19.38	15 tons manure [2]	.41	19.72
30 inches irrigation water [1]	.40	17.78			

[1] And varying quantities of manure. [2] And varying quantities of irrigation water.

The potassium content of the corn kernel increases with increase of the water applied during the growing season. Corn grown with 40 inches of irrigation water contains 12 per cent more potassium than that grown without irrigation water; that grown with 15 tons of manure contains 8 per cent more potassium than that grown without manure.

SUMMARY

Corn grown on a highly calcareous soil with and without irrigation water and manure showed a decrease in the nitrogen content of the kernel due to the irrigation water and an increase due to the manure, the nitrogen content of the grain being a function of the available nitrogen content of the soil. Although irrigation water increases the speed with which nitrogen is rendered soluble in the soil, the water carries the readily soluble nitrogen beyond the feeding area of the plant. Hence the nitrogen available to the plant, proportionately to the requirements, is greater under nonirrigation than under irrigation.

The ash, calcium, phosphorus, and potassium contents are increased with the application of irrigation water. All the constituents are greatly increased by manure. The results all bear out the idea that the increased ash and mineral constituents of the grain are due to an increased bacterial activity which increases the available plant food in the soil.

The increased calcium, potassium, and phosphorus and the narrower calcium-phosphorus ratio in the corn kernel grown with irrigation water make such corn more valuable for human and animal nutrition than similar corn grown without irrigation water.

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CLEANING MILKING MACHINES[1]

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INTRODUCTION

This paper gives the results of tests made for the purpose of comparing heat, chlorine, and salt and chlorine as agents for sterilizing milking machines. The word sterilizing is here used not in its technical meaning, but in the popular sense of denoting treatment which supposedly kills the organisms present with such a degree of completeness as to render the apparatus sanitary. In view of the various methods advocated for the sterilization of milking machines,[2] some comparative studies on three of the methods most generally used were considered desirable.

METHODS OF STERILIZING

Three single units were used in these tests. The units were washed and sterilized by the writer personally during the entire period, each unit receiving exactly the same treatment except in the sterilizing.

Immediately after milking, each unit was rinsed by drawing clean cold water through by vacuum, then it was washed with a brush in hot water (110° to 120° F.) containing washing powder, and then rinsed in clean hot water. Each unit (consisting of teat cups, claw, and milk tubes) was taken apart and thoroughly washed after each fourth or fifth milking. The units were sterilized as follows:

One unit was placed in a 5-gallon crock containing a chloride of lime solution (1 part available chlorine to 5,000 parts water), and one in a 5-gallon crock containing a saturated brine solution and chloride of lime (1 part available chlorine to 5,000 parts brine). These two units remained in the solutions for 24 hours or longer between milkings, except for the short period when they were used twice a day. Fresh solutions were made up after using for 8 or 10 milkings in cold weather, and after 4 or 5 in warm weather. The third unit was placed in hot water at 160° to 165° F. for 20 to 30 minutes just before milking, being kept in clean cold water the rest of the time.

A stock solution was made by dissolving a 12-ounce can of chloride of lime in 1 gallon of water and filtering into a glass bottle or jar. This was covered and kept in a cool, dark place. Sterilizing solutions were made by adding 1 ounce of stock solution to every gallon of water used.

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Each unit was given an identification mark through the tests. The milk buckets were sterilized with steam after washing. The units were used but once a day during the greater period of the tests, which ran for six months. Three or four cows were milked with each unit at a milking. As far as possible, the same cows were milked during the entire period. Also, the machines were rotated—i. e., a machine which milked one group of cows one day was used to milk another group the next day and so on—so that each machine milked the same cows about an equal number of times. Cow's teats and udders were washed and wiped with a clean cloth before milking. All cows chosen were normally low in udder bacteria.

Results of the tests are shown in Tables I, II, and III.

TABLE I.—*Summary of bacterial counts obtained, in cold weather, on samples of milk drawn with machines sterilized by three different methods*

Method	Number of samples of milk	Range in bacterial count per c. c.	Average bacterial count per c. c.	Samples of milk having a bacterial count of 10,000 per c. c. or lower	
				Number	Per cent of total
Heat	239	200 to 12,000	2,390	238	99.6
Chloride of lime	241	900 to 25,000	5,130	222	92.1
Salt and chloride of lime	241	800 to 24,000	5,250	218	90.5

TABLE II.—*Summary of bacterial counts obtained, in warm weather, on samples of milk drawn with machines sterilized by three different methods*

Method	Number of samples of milk	Range in bacterial count per c. c.	Average bacterial count per c. c.	Samples of milk having a bacterial count of 10,000 per c. c. or lower	
				Number	Per cent of total
Heat	103	600 to 6,700	2,330	103	100.0
Chloride of lime	103	2,700 to 160,000	17,300	59	57.3
Salt and chloride of lime	104	2,100 to 45,000	8,460	78	75.0

TABLE III.—*Summary of all bacterial counts (Tables I and II combined)*

Method	Number of samples of milk	Range in bacterial count per c. c.	Average bacterial count per c. c.	Samples of milk having a bacterial count of 10,000 per c. c. or lower	
				Number	Per cent of total
Heat	342	200 to 12,000	2,380	341	99.7
Chloride of lime	344	900 to 160,000	8,780	281	81.7
Salt and chloride of lime	345	800 to 45,000	6,220	296	85.8

As noted in Tables I, II, and III, the average bacterial counts on samples of milk drawn with the machine which was sterilized by the heat method were all very uniform, only one count going higher than 10,000 per c. c. There was very little difference between the results obtained by the chloride of lime method and by the brine or salt and chloride of lime method, during the cold weather. The results were very good, although not so good as those obtained by the heat method. During the warm weather, however, the bacterial counts accompanying the chloride of lime method and the salt and chloride of lime method rose considerably. Of the two methods the salt and chloride of lime method gave much better results than the chloride of lime. This was evidently due to the presence of the salt, which undoubtedly acted as a stabilizer in keeping the available chlorine from being given off too rapidly. However, the salt and chloride of lime had a marked corrosive action on some of the metal parts of the milker, which the heat method and plain chloride of lime solution did not have.

For a short period during one month the machines were used for two milkings a day, and during this time the unit which was sterilized with heat was placed in the hot water (160° to 165° F.) after it was washed and allowed to remain there until the next milking, the water cooling off gradually. The other two units were treated as formerly, being placed in their respective solutions after they were washed, and allowed to remain there until the next milking. Seventy-five samples of machine-drawn milk from each unit were collected during the month, 45 of which were from once-a-day milking and 30 from twice-a-day milking. Results are given in Table IV.

TABLE IV.—*Comparison of bacterial counts from milking once and twice a day*

Method	Once-a-day milking		Twice-a-day milking	
	Number of samples of milk	Average bacterial count per c. c.	Number of samples of milk	Average bacterial count per c. c.
Heat	45	2,380	30	2,450
Chloride of lime	45	5,220	30	5,160
Salt and chloride of lime	45	5,280	30	5,240

As noted in Table IV, there was practically no difference between the bacterial counts of the once-a-day and twice-a-day milking samples under the same sterilizing treatment.

All units were used for about 120 milkings, no rubber parts were replaced on any of them during this time, and all were still in good condition at the end of the experiment. Bacterial counts were made on samples of the sterilizing solutions of chloride of lime, and salt and chloride of lime, taken from the long milk tube. These counts varied considerably. There was no correlation between the age or bacterial counts of the solutions so taken and of the bacterial counts of the milk samples taken on the same days during the cold weather. During the warm weather, however, there was a direct relation (with one exception) between the age of the solution and the bacterial counts of the milk: the older the solution the higher the counts of the milk. A summary of the results is shown in Tables V and VI.

TABLE V.—*Comparison of age and bacterial count of sterilizing solution taken from long milk tubes, with bacterial count of the milk. (During cold weather)*

Chloride of lime				Milk		
Age of solution, in the number of the milking for which used	Number of samples	Range in bacterial count	Average bacterial count per c. c.	Number of samples	Range in bacterial count	Average bacterial count per c. c.
First	2	0	0	6	1,700 to 25,000	9,430
Second	4	0 to 3	2	12	1,600 to 10,200	3,730
Third	3	0 to 4	2	9	1,100 to 12,000	4,840
Fourth	4	0 to 4	1	12	900 to 11,000	4,670
Fifth	5	0 to 1	1	15	2,700 to 13,300	5,360
Sixth	2	0 to 1	1	6	2,100 to 9,800	5,070
Seventh	3	0 to 2	1	9	2,200 to 14,000	4,330
Eighth	7	0 to 300	44	21	1,400 to 11,400	4,710
Ninth	4	0 to 10	3	12	1,100 to 8,400	4,970
Tenth	3	1 to 20	7	9	2,300 to 11,000	5,410
Salt and chloride of lime solution				Milk		
First	3	0 to 3	1	8	1,200 to 3,900	2,800
Second	3	0	0	9	800 to 6,800	3,500
Third	3	0 to 7	3	11	1,200 to 12,500	4,940
Fourth	4	1 to 4	3	12	1,000 to 11,000	4,280
Fifth	6	0 to 400	69	18	1,600 to 12,000	4,950
Sixth	3	0 to 3	1	9	1,100 to 9,100	5,870
Seventh	4	0 to 8	3	12	1,000 to 20,000	5,340
Eighth	6	0 to 250	63	18	1,400 to 12,600	5,880
Ninth	4	0 to 440	115	12	1,800 to 12,800	5,480
Tenth	2	0 to 40	20	6	1,500 to 8,800	4,500

TABLE VI.—*Comparison of age and bacterial count of sterilizing solution taken from long milk tubes, with bacterial count of the milk. (During warm weather)*

Chloride of lime solution				Milk		
Age of solution, in the number of the milking for which used	Number of samples	Range in bacterial count	Average bacterial count per c. c.	Number of samples	Range in bacterial count	Average bacteria count per c. c.
First	5	0 to 200	44	15	2,700 to 19,300	8,410
Second	7	1 to 20	5	21	4,200 to 42,000	11,840
Third	7	1 to 5,000	859	21	3,800 to 63,000	14,540
Fourth	7	2 to 48,000	11,004	21	3,400 to 160,000	23,970
Fifth	5	20 to 10,000	2,286	15	5,300 to 128,000	24,870
Salt and chloride of lime solution				Milk		
First	6	0 to 12	4	18	2,500 to 9,400	4,630
Second	7	1 to 30	10	21	2,100 to 24,400	7,970
Third	7	0 to 180	37	21	3,100 to 36,000	9,350
Fourth	7	1 to 1,440	433	21	3,500 to 45,000	11,030
Fifth	5	10 to 720	215	15	3,100 to 28,000	10,460

SUMMARY AND CONCLUSIONS

Comparative tests of the three methods commonly used for sterilizing milking machines—namely, heat, chloride of lime, and a mixture of common salt and chloride of lime—showed that the heat method, under conditions as nearly identical as possible, gave more uniform and appreciably lower bacterial counts than did the other two methods.

There was practically no difference in the results obtained by the chloride of lime method and the salt and chloride of lime during the colder weather. About 92 per cent of the samples of milk drawn with the unit sterilized in the chloride of lime solution had bacterial counts of 10,000 per c. c. or lower. About 90 per cent of the samples of milk drawn with the unit sterilized in the salt and chloride of lime solution had bacterial counts of 10,000 per c. c. or lower.

Neither of these two methods gave as good results in warm weather as they did in cold weather; and the salt and chloride of lime method gave much better results than did the plain chloride of lime. Only about 57 per cent of the samples of milk drawn with the unit sterilized in the chloride of lime solution had a bacterial count of 10,000 per c. c. or lower, and about 75 per cent of the samples drawn with the unit sterilized with the salt and chloride of lime solution had a count of 10,000 per c. c. or lower. The salt and chloride of lime solution corroded some of the metal parts.

The results obtained in these experiments were chiefly concerned with once-a-day milking; check samples taken from twice-a-day milking, however, showed practically no difference, there being a variation of less than 100 bacteria per c. c. in the averages of once-a-day and twice-a-day milking for each method. During this period when samples were taken twice a day the unit sterilized with heat was allowed to remain in the hot water until the next milking, the water cooling gradually. The other two units were treated as formerly, being placed in their respective sterilizing solutions after they were washed, and allowed to remain there until the next milking.

Bacterial counts made on samples of the sterilizing solutions taken from the long milk tubes of the two units sterilized in the chloride of lime and the salt and chloride of lime solutions, varied considerably.

In cold weather, there was no correlation between the age or bacterial counts of the solutions and the bacterial counts of the milk samples taken on the same days. During the warm weather, however, there was a direct relation (with one exception) between the age of the solution and the bacterial count of the milk; the older the solution, the higher the bacterial count of the milk.

The experiments indicated that making up a fresh sterilizing solution of chloride of lime, or of salt and chloride of lime, once a week in cold weather, would undoubtedly be sufficient to insure a good grade of milk, if the units were thoroughly washed and the solution kept free from all foreign matter. During warm weather, however, fresh chloride of lime solution should be made daily, even under the most cleanly conditions; and new salt and chloride of lime solutions should be made up about every other day.

LABORATORY TESTS ON EFFECT OF HEAT ON SEEDS OF NOBLE AND SILVER FIR, WESTERN WHITE PINE, AND DOUGLAS FIR [1]

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To test the ability of the seed of noble fir (*Abies nobilis*) and silver fir (*A. amabilis*) to withstand the effects of forest fires, samples of seed were subjected for 10 hours each to dry heat of varying temperatures from 100° to 300° F. and to moist heat of 100° to 240°. The samples consisted of 225 seeds for each test. The moist condition was produced by keeping water in the heating oven to maintain the air as near the point of saturation as possible.[2]

Duplicate tests with Douglas fir (*Pseudotsuga taxifolia*) and western white pine (*Pinus monticola*) were made at the same time.

After heating, 25 seeds were taken from each sample for microscopic examination, and the remaining 200 seeds were sown in the nursery in drills, a separate sample in each drill.

The seeds for these germination tests were sown in the nursery at the end of August. A little germination appeared in the fall of that year, but most of it occurred during the following season. The results are shown in Table I.

TABLE I.—*Total germination from samples of 200 seeds each of noble, silver, and Douglas fir, and western white pine heated for 10 hours*

Temperature (° F.)	Noble fir	Silver fir	Douglas fir	Western white pine
	Number	*Number*	*Number*	*Number*
DRY HEAT				
100	32	3	128	174
140	0	1	124	191
160	9	0	123	157
180	3	0	146	167
200	0	0	1	47
220	1	0	0	0
240	0	0	0	0
Not heated	4	3	110	188
MOIST HEAT (AIR SATURATED)				
100	34	0	130	167
140	11	16	120	165
160	0	0	48	97
180	0	0	0	0
200	0	0	0	0
220	0	0	0	0
240	0	0	0	0
Not heated	4	3	110	188

[1] Received for publication Oct. 28, 1924; issued September, 1925.

[2] For heating in moist air above 240° a pressure oven is required.

The inferior quality of the true fir seed renders these tests mainly of interest in showing results for the pine and Douglas fir. For these species the limit of heat under which the seeds remained viable was between 200 and 220° F. dry heat and considerably below that for moist heat. The fact, however, that one true fir seed germinated after the application of 220° of dry heat shows at least the possibility of seeds retaining their vitality under this temperature for several hours.

From the fact that only one seed withstood intense heat successfully one might conclude that seed subjected to the heat of forest fires in the cone (which would in some degree be moist heat) has small likelihood of retaining its viability. It must be remembered, however, that cones scorched by an ordinary crown flash are heated for only a short time, so that the seed rarely reaches very high temperatures.

On the other hand, the comparatively low temperatures of the 10-hour tests that resulted in appreciable germination indicate that in a crown fire of devastating intensity there is small chance for the seed of any of these species to survive solely through the protection of cones while on the trees, although it may be possible that some seed will escape the fire in this way.

Observations of the condition of the seeds during the heating tests may be briefly detailed as follows:

SILVER FIR

The silver fir seed in its normal condition has a glistening endosperm; brownish, translucent seed coats; and a smooth surface. The small blisters in the exocarp are well filled with pitch. When the seed was subjected to dry heat there was no apparent change until 140° F. was reached, when a slight drying of the seed was noticeable. At 160° the pitch began to ooze from the seed coats and the endosperm was slightly whiter. As the temperature rose higher, this drying of the endosperm became more and more apparent. At 200° so much pitch had exuded from the seeds that they began to stick together. This condition progressed until, at 300° of dry heat, the seeds browned, and so much pitch had oozed out that they were stuck to the dish.

With the seed given moist heat, the only apparent change was the oozing of the pitch until, at the highest temperature, 240° F., the seeds stuck to one another, but not so much so as in the dry-heated seeds. No change in the endosperm in drying or in color was apparent.

NOBLE FIR

The normal noble fir seed has a smooth exocarp, with small pitch pockets well filled with pitch. The seed coats are translucent when taken separately; and the endosperm has a glistening color, but it usually does not fill the ovary. When the seed of the noble fir was dry heated, there was no change apparent up to 160° F. Then the exocarp turned darker and shiny, and this condition became more marked with the continued rise of temperature. At 180° there was an appreciable drying of oils in the endosperm. These conditions became more noticeable until, at 300°, the seed was shriveled, and a great deal of pitch exuded and the endosperm was darkened.

In the moist-heat series this change of color was not so apparent, and the shriveling of the seed did not occur.

WESTERN WHITE PINE

The normal western white pine seed has an exocarp with a slight grayish bloom; the endosperm is very oily and smooth and fills the entire ovary. No changes were apparent until 160° F. was reached, when the exocarp began to darken, and the pitch began to ooze from the seed. These changes became more and more apparent as the temperatures became higher. At 200° drying of the endosperm became noticeable. At 240° so much pitch had oozed from the seed coats that the seeds stuck together and stuck to the dish. At 300° the exocarp was very brown and almost charred where in contact with the dish, while the drying of the endosperm was marked.

The seeds subjected to moist heat did not show these changes of color or shriveling of endosperm, but the amount of oozed pitch was about the same.

DOUGLAS FIR

The normal Douglas fir seed has a mottled, dark-brown exocarp and a whitish clear endosperm which entirely fills the ovary. There was no change apparent until 180° F. was reached, when the exocarp became slightly darker, and shiny. This became more noticeable until, at 240°, the seeds had exuded enough pitch to stick together and stick to the dish. The endosperm did not show any change until 240°, when it was noticeably drying out and slightly shriveled. At 300° the exocarp was a very dark brown, the endosperm was noticeably shriveled, and a great deal of pitch had oozed out.

The seeds in the moist-heat series did not show this shriveling of the endosperm, and the change of color in the exocarp was not so marked, although about the same amount of pitch came from the seeds.

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